Multi-Speed
***C**ompact **D**isc **R**ecordable*

System Description
Volume 2

Version 1.3

August 2006

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I. General

This document describes the Multi-Speed version of the Recordable Compact Disc System: "CD-R Multi-Speed".

I.1 Scope

The CD Recordable (CD-R) system gives the opportunity to write once and read many times CD information. The recorded CD-R disc is 'Red Book compatible', so it can be played back on conventional CD-players. The CD-R format gives the possibility for both Audio and Data recording.

I.2 General Description

In the CD-R system the disc contains recording material which shows a reflection decrease due to recording. After recording, the CD-R disc satisfies the specifications as written in the chapter DISC SPECIFICATION of the Red Book. The CD-R disc contains a wobbled pre-groove for tracking, CLV speed control and timing purposes. Recording takes place in the groove.
This document defines 6 types of discs allowing recording speeds up to 16x, 20x, 24x, 32x, 40x or 48x nominal CD speed using a high-speed write strategy.

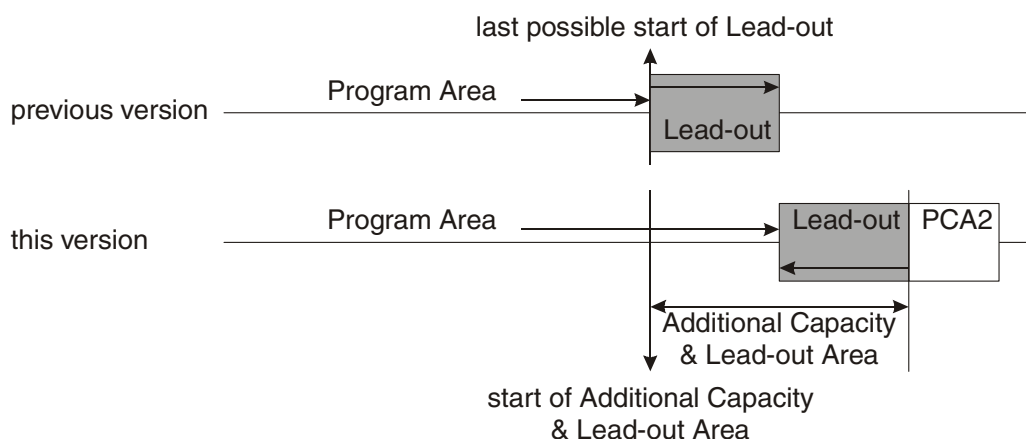
Warning:

Due to technical reasons, it may be the case that during playback and recording at high rotation speed the disc and drive suffers significant technical damage.

Therefore, sufficient care should be taken by the disc manufacturer to produce discs allowing recording and playback at high rotation speed, even after rough disc handling.

Sufficient care should be taken by the drive manufacturer to guarantee that the loading-tray is closed, and remains to be so, during playback and during recording.

For backwards compatibility with recorders compliant to Volume 1, also speeds of 1x (optional), 2x and 4x nominal CD speed using the write strategies according to Volume 1 shall be supported.
Multi-Speed CD-R discs that can be recorded at **1x, 2x and 4x according to the descriptions in Volume 1** are called *"**Full-range Volume 1 compliant**"*.
Only Full-range Volume 1 compliant Multi-Speed CD-R discs are allowed for Unrestricted Use (use in Consumer CD-recorders, see chapter IV.4.1.3).

To enable high speed power calibration, a second Power Calibration Area (PCA2) at the outer diameter of the disc has been specified.
Additional disc capacity could be realized by giving the opportunity to fully exploit all area up to the PCA2 for User Data storage with only the minimum Lead-out required. When the Lead-out is being positioned as close as possible before the PCA2, the remaining area preceding the Lead-out can all be used for User Data storage.
The area between the address mentioned in ATIP Special Information 3 and the PCA2 is now called: “Additional Capacity & Lead-out Area”.
Therefore the “last possible start time of Lead-out Area”, given in Special Information 3, has been renamed “Start of Additional Capacity & Lead-out Area” (SAL).
The length of this area is indicated as the “Length of Additional Capacity & Lead-out Area” (LAL) in the Additional Information 1 in ATIP code.

Remark 1:
Like the CD-DA system (Red Book, pages 84 up to 86), the CD-R system offers the possibility of an 8 cm "CD-single".

Remark 2:
When the chapter DISC SPECIFICATION of the Red Book is being referred to, pages 74 up to 83 are excluded (description of CD-Video).

Remark 3:
For Data applications, the term "Red Book" in this document must be replaced by "Yellow Book" or "Green Book" if necessary for recording Data instead of Audio information.

I.3 References and conformance

CD-R conforms to the mandatory requirements specified in this document. All parts in this document are mandatory unless they are specially defined as recommended or optional or informative.

Note:

Due to advances in technology and market requirements, System Descriptions might need to be extended after some time. This could mean that new items, such as e.g.: new subcode modes and pointers, new ATIP formats, new data structures or definitions for reserved bits/bytes, may have to be added to a System Description.

System designers should take notice of this in the design of their equipment.

CD-R also conforms to the applicable parts of the System Descriptions or international standards that are listed below:

- CD-DA: Compact Disc Digital Audio, specified in the System Description Compact Disc Digital Audio ("Red Book"), Royal Philips Electronics and Sony Corporation.
- CD-ROM: Compact Disc Read Only Memory, specified in the System Description Compact Disc Read Only Memory ("Yellow Book"), Royal Philips Electronics and Sony Corporation.
- CD-i: Compact Disc Interactive, specified in the CD-I Full Functional Specification ("Green Book"), Royal Philips Electronics and Sony Corporation.
- CD-ROM XA: Compact Disc Read Only Memory eXtended Architecture, specified in the System Description CD-ROM XA, Royal Philips Electronics and Sony Corporation.
- CD-R: Compact Disc Recordable, specified in the System Description Recordable Compact Disc Systems, part II: CD-R, volume 1: 1x/2x/4x ("Orange Book"), Royal Philips Electronics and Sony Corporation.
- CD-RW: Compact Disc ReWritable, specified in the System Description Recordable Compact Disc Systems, part III: CD-RW, volume 1: 1x/2x/4x ("Orange Book"), Royal Philips Electronics and Sony Corporation.
- CD-RW HS: Compact Disc ReWritable High-Speed, specified in the System Description Recordable Compact Disc Systems, part III: CD-RW, volume 2: High-Speed ("Orange Book"), Royal Philips Electronics and Sony Corporation.
- Multisession CD: Multisession Compact Disc, specified in the Multisession Compact Disc Specification, Royal Philips Electronics and Sony Corporation.
- CD-logos: CD Logo Guide Royal Philips Electronics
- ISO 646: Information processing ISO 7-bit coded character set for information interchange. Ref. No. ISO 646 : 1983 (E).

I.4 Definitions

I.4.1 General

⟨x⟩	:	⟨x⟩ denotes the average value of parameter x.
Δx	:	Δx = x - ⟨x⟩ denotes the deviation of the instantaneous value of parameter x from the average value.
ACL	:	Additional Capacity & Lead-out Area. See paragraph IV.4.3.
ATER	:	**AT**IP **E**rror **R**ate. Number of erroneous ATIP frames in proportion to the total number of frames, averaged over any 10 seconds.
ATIP	:	**A**bsolute **T**ime **I**n **P**re-groove. With an additional modulation of the "Wobble", the "Groove" contains a time code information called ATIP, see chapter IV.
Audio disc	:	A recorded disc, which is not a Data disc.
Audio Session	:	A Session containing Audio Tracks only.
Audio Track	:	A Track which is not a Data Track.
Block	:	A unity of 2352 bytes as defined in the Yellow Book (page 100).
CLV	:	**C**onstant **L**inear **V**elocity is the speed with which the pre-groove or the recorded pits and lands on the disc pass the laser spot in tangential direction.
Consumer CD-recorder	:	A CD-recorder designed and manufactured for consumer use and solely for recording signals in accordance with the CD-DA Format (Red Book).
CW	:	**C**ontinuous **W**ave. The laser light output is at a constant level.
Data disc	:	A disc on which every Session contains one or more Data Tracks.
Data Session	:	A Session containing one or more Data Tracks.
Data Track	:	A Track, which is designated as "Data Track" in CONTROL of the subcode Q-channel.
Deviation	:	effect length deviation is the length error of a specific (I_3 .. I_{11}) pit or land compared to its nominal value, as measured by Time Interval Analysis.
Effect length	:	The average length of a specific (I_3 .. I_{11}) pit or land, as measured by Time Interval Analysis (see Red Book).
EFM	:	**E**ight to **F**ourteen **M**odulation. See chapter VI.
EFM frame	:	A group of 588 channel bits, representing an EFM sync pattern, one byte of subcode information, 24 bytes of user data and 8 bytes of CIRC error correction parity symbols (see Red Book). The duration at nominal speed equals about 136 μsec.
Finalization	:	The action in which (partially) unrecorded tracks are finished and the Lead-in and/or Lead-out areas are recorded with the appropriate TOC subcode.
Final Session	:	The last Session on a CD-R disc can be designated as the Final Session. Addition of Sessions after the Final Session is not possible.
FWHM	:	Full Width Half Maximum
(pre-) Groove	:	The guidance track in which clocking and time code information is stored by means of an FM modulated wobble.

Hybrid Disc	:	A Multisession disc of which the first Session is mastered. On a hybrid disc, recorded and mastered information may co-exist.
Jitter	:	The 1 σ value of the time variations between leading and trailing edges of a specific (I_3..I_{11}) pit or land as measured by Time Interval Analysis (see Red Book).
LAL	:	Length of Additional Capacity & Lead-out Area (See paragraph IV.4.4.
Land	:	Land is characterized in the following way: When radial signals are concerned, land is defined as the area between the grooves. When HF signals are concerned, land is defined as the area between the pits in tangential direction.
Laser Modulation	:	During recording, the laser is switched on and off according to the "Write Strategy".
Mastered information	:	Information, stored as pits on the disc during the manufacturing process of the disc (when making the "master").
Multisession disc	:	A disc that contains or can contain more than one Session (indicated in the first Lead-in area in mode 5 of the subcode Q-channel).
m_{11}	:	Denotes the modulation I_{11}/I_{top}, obtained under test conditions described in chapter II.5.
Nominal CD Speed	:	The CLV that will result in an average EFM bitclock frequency of 4.3218 MHz or in an average pre-groove wobble frequency of 22.05 kHz.
Nx nominal CD speed	:	A CLV speed, which is N times the Nominal CD Speed.
Normalized **P**ush-**P**ull **R**atio (NPPR)	:	The resulting value, when the normalized push pull amplitude before recording is divided by the normalized push pull amplitude after recording. See also chapter I.4.4: Signals after recording. - Push pull amplitude before recording is normalized to the groove level I_g before recording (see chapter I.4.4). - Push pull amplitude after recording is normalized to the averaged groove level I_{ga} after recording (see chapter I.4.4).
OPC	:	**O**ptimum **P**ower **C**ontrol: see attachment XIII.3.
ORH	:	Outer Rim Height: see Figure XII-20 and Figure XII-21
PCA1	:	**P**ower **C**alibration **A**rea 1: see chapter I.4.2.
PCA2	:	**P**ower **C**alibration **A**rea 2: see chapter I.4.2
Pits	:	Recorded or mastered I_3 .. I_{11} effects.
PMA	:	**P**rogram **M**emory **A**rea: see chapter I.4.2.
Pre-groove	:	The guidance track in which clocking and time code information is stored by means of an FM modulated wobble.
Professional CD-recorder	:	A CD-recorder designed and manufactured for professional use and solely for recording signals in accordance with the CD-DA Format (Red Book), the CD-ROM Format (Yellow Book) and/or the CD-i Format (Green Book). Note: this professional category includes all CD-recorders other than “Consumer CD-recorders”.

P_{WO}	:	The optimum write power for the creation of "pits" during a recording, as determined by the OPC procedure (see Figure II-1 and attachment XIII.3).
SAL	:	start time of Additional Capacity & Lead-out Area. See paragraph IV.4.3.
Random EFM	:	Random EFM data are characterized by: - In the main channel: random data symbols (e.g. a recorded white noise audio signal). - In the subcode channel: all subcode bytes, except the sync and the CRC, must be set to a fixed value per subcode frame, preferably "FF" or "00".
Recorded area	:	An area (or Track) recorded with an EFM signal containing User Data and Subcode Q.
Recorded Information	:	Information, stored as pits on the disc during the recording process of the CD-R disc.
Reserved	:	“Reserved” in relation to a value means: the specified value(s) shall not be used. In future standards, these value(s) can be assigned. "Reserved” in relation to a field means: the use of the field(s) is not specified and the value(s) in the field(s) must be set to zero. In future standards, the use of these fields can be defined.
RPM	:	Revolutions per minute
Session	:	An area on the disc consisting of a Lead-in area, a Program area and a Lead-out area.
Single Session disc	:	A disc which is not a Multisession disc.
Stacking ring area	:	The ring area between the clamping and the information area. In this area diverse shapes with protrusions and recesses are allowed, both on the read-out and label side. It is called the stacking ring area as this area is most used for creating a stacking ring at the read-out side of the disc. See Figure XII-19.
TDB	:	**T**rack **D**escriptor **B**locks in the Pre Gap of a data Track contain information about the Track attributes. (see chapter V.6.5)
TOC	:	**T**able **O**f **C**ontents: in the Lead-in Area the subcode Q-channel contains information about the Tracks on the disc.
Unbalance of disc U_d	:	$U_d = m_d * r$ [g.mm], in which m_d = mass [grams] of disc and r = distance [millimeters] between centre of gravity and geometrical centre of disc. When the disc is rotating at a rotational frequency f_{rot} [Herz], then the resulting Unbalance Force becomes $F_U = U_d * \omega^2 * 10^{-6}$ [Newton], in which $\omega = 2\pi * f_{rot}$.
Unrecorded area	:	An area in which no signal has been recorded.
Variation	:	The variation of a parameter x is defined as the ratio $\Delta x / \langle x \rangle$.
Wobble	:	The pre-groove in the disc is not a perfect spiral but is wobbled with: - a typical amplitude of 30 nm, - a spatial period of 54 to 64 µm. (See chapter IV)
Write	:	The action in which information is recorded in an unrecorded area of the CD-R disc.

Write Strategy	:	The shape of the HF write signal used to modulate the power of the laser. The Write Strategy that must be used for recordings necessary for disc measurements is described in chapter II.3.3: Write strategies for media testing.

I.4.2 Disc Lay-out

The recorded area on a disc can be subdivided into Sessions, where a **Session** consists of a Lead-in Area, a Program Area and a Lead-out Area.
A Session is called finalized, when the Program Area does not have unrecorded areas and the Lead-in Area and the Lead-out Area both have been recorded with the appropriate subcode mode 1 and mode 5.
A Session is called non-finalized, when the Lead-in Area and the Lead-out Area are unrecorded.
All possible states of a Session are defined in Figure I-1.

Program Area	Lead-in & Lead-out area	Session state
contains unrecorded areas	recorded with subcode mode 1 & 5	**not allowed**
contains unrecorded areas	unrecorded	non-finalized
fully recorded	unrecorded	non-finalized
fully recorded	recorded with subcode mode 1 & 5	finalized

Figure I-1 Possible states of a Session

In general, three **recording states of the disc** are defined:

the Unrecorded disc,	of which the layout is given in Figure XII-1.
the Partially Recorded disc,	of which an example of a layout (for a single Session) is given in Figure XII-2.
the Finalized disc,	of which an example of a layout (for a single Session) is given in Figure XII-3.

In case of a Multisession disc, the last Session may be partially recorded (non-finalized) or finalized; all previous Sessions must be finalized. An example of a Multisession disc is given in Figure XII-18.

Remarks:
- Only Finalized Sessions can in general be played back on conventional CD players.
- For further descriptions of each disc area, see chapter V.
- For further descriptions of the Multisession disc, see chapter XI.

Unrecorded disc:
The Information Area of an unrecorded CD-R disc contains a pre-groove with CLV clocking information (wobble) and a time code (ATIP).
In addition to the time code encoded in ATIP, during the Lead-in Area the CD-R disc also contains extra information, such as: disc identification, write power, speed range and OPC parameters (see chapter IV).

Partially Recorded disc:
The Data Organization of the partially recorded disc is defined in chapter V and includes:

1: Power Calibration Area 1 and /or 2 (PCA1, PCA2): partially recorded.
The PCA1 and PCA2 are reserved for determining the correct writing power of a disc, see chapter V.3. As well in PCA1 as in PCA2 all 100 partitions are used sequentially.

2: Program Memory Area (PMA): partially recorded.
The PMA must reflect the complete track information of all Sessions on the CD-R disc. (see chapter V.4)
remark: In case the *Incomplete Track* features are used, the PMA may not always reflect the exact track information of the Program Area (see chapter V.4.1.2).

3: One or more Session(s):
all Sessions, except the last Session: *finalized.*
Lead-in Area: recorded with subcode mode 1 & 5
The Lead in Area has been recorded with the **T**able **O**f **C**ontents according to the specifications in chapter V.5.
Program Area: fully recorded
In the Program Area the Tracks with user information have been recorded according to the specifications in chapter V.6.
Lead-out Area: recorded with subcode mode 1 & 5
The Lead-out Area has been recorded according to the specifications in chapter V.7 or chapter XI.5.

the last (or only) Session: *non-finalized.*
Lead-in Area: unrecorded
This area is reserved for the recording of the Lead-in Area with the **T**able **O**f **C**ontents according to the specifications in chapter V.5.
Program Area: partially recorded
In the Program Area the Tracks with user information have been or will be recorded according to the specifications in chapter V.6.
Lead-out Area: unrecorded
This area is reserved for the recording of the Lead-out Area according to the specifications in chapter V.7 or chapter XI.5. This area starts right after the Program Area. When finalizing a Session, the Lead-out is recorded right after the last recorded Track.

Finalized disc:
A finalized disc is a disc in which all Sessions are finalized.
A finalized Session is a Session with a fully recorded Program Area (no unrecorded areas), a Lead-in Area with a Table Of Contents reflecting the track information of the related Program Area, and a Lead-out Area.
After finalizing the disc, all Sessions can in general be played back on conventional CD players.

I.4.3 Writing modes

The CD-R system gives the opportunity to write information in different interrupted write actions e.g. at a different time, on a different recorder. Writing on a CD-R disc can take place only in non-finalized Sessions.

A CD-R recorder in general can use the following writing modes:

Uninterrupted writing: - Disc At Once (DAO),

Incremental writing: - Session At Once (SAO),
- Track At Once (TAO),
- Packet writing.

A **summary of the main characteristics** of these writing modes is given below. The detailed requirements for writing and linking can be found in chapter V.

DAO: complete disc is written in one write action

All areas are written in one uninterrupted write action:

- the Track information of the disc is recorded in the Lead-in Area(s) (same format as for read-only discs);
- no link points are used;

⇒ adding data is not possible.

SAO: complete Session is written in one write action

Lead-in Area, Program Area and Lead-out Area are written in one uninterrupted write action:

- the Track information of the Session is recorded in the Lead-in Area and in the PMA;
- subcode mode 5, point=B0 in the Lead-in Area gives the start of the next Program Area;

⇒ adding data in a new Session is possible.

TAO: complete Track is written in one write action

Pre Gap + Track content + Post Gap are written as one packet:

- the start and stop time of the Track are recorded in the PMA;
- the Track starts and ends with a link point;

⇒ adding data in a new Track is possible.

Packet writing:

writing of fixed or variable size packets in an Incomplete Track or Reserved Track

The Track has to be initialized by writing the Pre Gap with Track Descriptor Blocks. The Pre Gap ends with a link point:

- the start time and stop time of the Track are recorded in the PMA;
- each added packet starts and ends with a link point;

⇒ packets can be added to the Track.

I.4.4 Signals

Signals before recording:

Signal		Description
I_0	:	*Blank area level*
I_l	:	*Land level*
I_g	:	*Groove level before recording*
$RC_b = 2 * \frac{(I_l - I_g)}{(I_l + I_g)}$	:	*Radial Contrast before recording*
$\frac{\lvert I_1 - I_2 \rvert}{I_g}$ at 0.1µm radial offset	:	*Push Pull magnitude before recording* $(I_1$-$I_2)$ is measured after low pass filtering ($f < 5$ kHz). For explanation, see attachment XIII.6 and Red Book chapter 15.1.
$I_W = (I_1 - I_2)$	:	*Wobble signal* $(I_1$-$I_2)$ is measured after band-pass filtering (10 kHz $< f <$ 30 kHz).
$\frac{I_{W(rms)}}{\lvert I_1 - I_2 \rvert_{(pp)}}$	:	*Normalized wobble signal* See attachment XIII.7.

Signals after recording:

Signal		Description
I_{top}	:	*Top level of recorded I_{11} signal* See Red Book chapter 14.
$I_{ga}, (I_{la})$	:	*Averaged groove (land) level after recording* I_{ga} (I_{la}) is defined as the averaged HF signal (τ = 15 µs), measured in the groove (on land), before AC coupling.
$RC_a = 2 * \frac{(I_{la} - I_{ga})}{(I_{la} + I_{ga})}$	:	*Radial Contrast after recording*
$\frac{I_3}{I_{top}}, \frac{I_{11}}{I_{top}}$	:	*Modulation amplitudes of I_3 and I_{11} signals* See Red Book chapter 14.
$\frac{I_3}{I_{11}}$	:	*Ratio of I_3 and I_{11} signals*

$\frac{\lvert I_1 - I_2 \rvert}{I_{top}}$ at 0.1μm radial offset	:	*Push Pull magnitude after recording* $(I_1\text{-}I_2)$ is measured after low-pass filtering (f < 5 kHz). For explanation, see attachment XIII.6 and Red Book chapter 15.1.
$R_{top} = R_0 * \frac{I_{top}}{I_0}$	:	*Reflectivity of the recorded disc relative to I_{top}* R_0 is the reflectivity of a blank area of the disc, see attachments XIII.2 and XIII.8.
$\frac{\lvert I_1 - I_2 \rvert / I_g}{(\lvert I_1 - I_2 \rvert)_a / I_{ga}}$	:	*Normalized Push Pull Ratio* (NPPR) See chapter I.4.1 and attachment XIII.6. - $\lvert I_1\text{-}I_2 \rvert / I_g$ is measured before recording. - $(\lvert I_1\text{-}I_2 \rvert)_a / I_{ga}$ is measured after recording.

II. Disc Specification

II.1 General

In this chapter the atmospheric conditions, the optical pick-up unit, the write strategy and nominal conditions for ***Multi-Speed Media*** testing are defined, which must be used for test recording and measurement of all characteristics.

II.2 Conditions for Multi-Speed Media testing at low speeds

To ensure compatibility with recorders compliant with volume 1, the media shall be tested at 2x and 4x nominal CD speed according to the conditions as specified in chapter II of the System Description Recordable Compact Disc Systems, part II: CD-R, volume 1: 1x/2x/4x. Full-range Volume 1 compliant discs (see chapter I.2) shall also be tested at 1x.

II.3 Conditions for Multi-Speed Media testing at high speeds

To check compliance of the Multi-Speed Media with this volume 2, the media shall be tested at the 2 recording speeds defined in chapter IV.4.4:

- Lowest Test Speed (LTS),
- Highest Test Speed (HTS).

II.3.1 Standard atmospheric conditions for testing.

Measurements and mechanical checks are to be carried out at any combination of temperature, humidity and air pressure within the following limits, unless otherwise specified:

Ambient temperature : 23 ^{o}C ± 2 ^{o}C
Relative humidity : 45% to 75%
Air pressure : 86 kPa to 106 kPa.

II.3.2 The optical pick-up units for disc measurements.

Three different optical pick-up units are defined for measurements:

(1) The "**Read Only optical pick-up"** for measurement of the characteristics in chapter 0: "The recorded disc", except jitter & effect length.
The specification of this pick-up unit is equal to the specification of the pick-up in the Red-Book on page 2:

Wavelength : 780 ± 10 nm
NA : 0.45 ± 0.01
Polarization : circular
Wavefront distortion : < 0.05 λ (RMS value)
Rim intensities:
Tangential : > 0.5
Radial : > 0.5
Laser read power : < 0.7 mW, CW in the central spot.

(2) The **"Read Only optical pick-up"** for measurement of β **and jitter & effect length**, see chapter 0.14:

Wavelength : 780 ± 10 nm
NA : 0.45 ± 0.01
Polarization : perpendicular to the tracks
Wavefront distortion : < 0.05 λ (RMS value)
Rim intensities:
Tangential : > 0.7
Radial : > 0.5
Laser read power : < 0.7 mW, CW in the central spot.

(3) The **"Recorder optical pick-up"** for measurement of all characteristics in chapter II.4: "The unrecorded disc", and for the recordings which are necessary for disc measurements. The specification of this pick-up unit is (at P_W = 24 mW and $T_{ambient}$ = 23 ± 2 ^{o}C):

Wavelength : 786 ± 2 nm
NA : 0.50 ± 0.01
Polarization : circular
Wavefront distortion : < 0.05 λ (RMS value)

Spot shape and orientation:
Shape : oval spot
Orientation : angle of axes relative to the track = 45° ± 5°
Intensities at RIM of aperture:
in direction of highest intensity : 0.57 ± 0.05
in direction of lowest intensity : 0.17 ± 0.05
FWHM of intensity in direction of lowest intensity: 0.55 ± 0.03 of full aperture diameter

Laser power:
Reading : < 0.7 mW, CW in the central spot.
Writing : according to "Write strategy" and "OPC", see below.

remark 1:
All signal measurements are done **without read equalization**. In practical players and recorders however, read equalization is recommended in order to improve margins.

remark 2:
Specifications described in section 0: "the recorded disc", must be fulfilled over the wavelength range 770 < λ < 830 nm (see Red Book page 12 and attachment XIII.8)

II.3.3 Write strategy for media testing

During the recordings necessary for disc measurements, using the "recorder optical pick-up (3)" specified above, the laser power is modulated according to the following write strategy:

T is the length of one clock cycle.
Each I_n Pit (n = 3..11) is recorded by applying a [(n-θ)∗T] **W**rite **P**ulse, if the preceding EFM runlength was ≥ 4T.
Each I_n Pit (n = 3..11) is recorded by applying a [(n-θ-Δ)∗T] **W**rite **P**ulse, if the preceding EFM runlength was = 3T.
The **W**rite **P**ulse height of each I_n for n = 4..11 is P_W.
The **W**rite **P**ulse height of I_n for n = 3 is $P_W + \Delta P$. (see Figure II-1).
The power level between the write pulses is P_B.

Rise and fall times of all signal transitions (from 10% to 90% of stepsize) shall be ≤ 2.5 ns.
Signal overshoots shall be ≤ 10% of the stepsize.

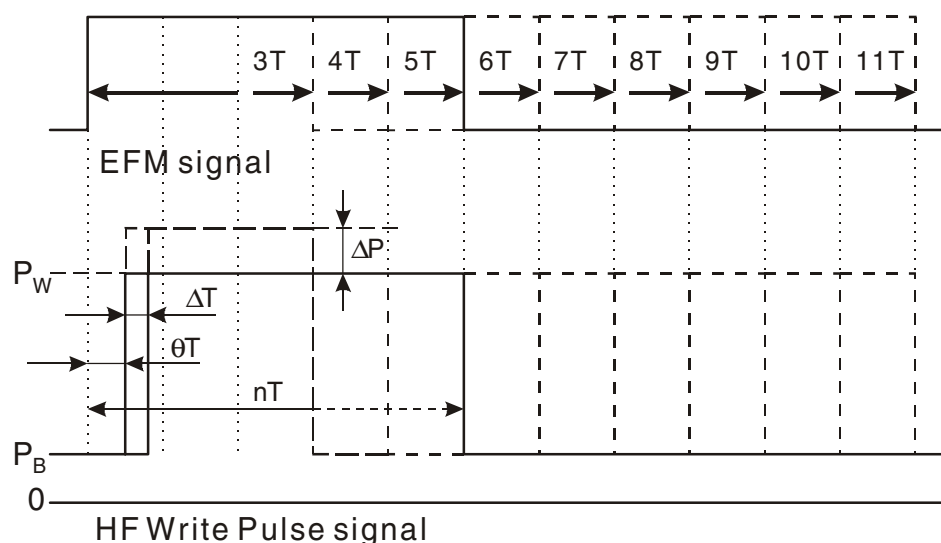



Figure II-1 Write strategy for use with pick-up (3)

II.3.4 Nominal conditions for media testing

All media shall be tested at the LTS (Lowest Test Speed) and the HTS (Highest Test Speed) according to the Conditions for Multi-Speed Media testing at high speeds (see chapter II.3).
The write strategies and β-ranges for making test recordings at the specified speeds are given in . All media shall fulfill the requirements mentioned in the following chapters, when tested under these conditions.

parameter: / recording speed:	(n-θ)T	ΔT	ΔP	β-range
LTS	(n-0.5)∗T	T/16	0.04∗P_W	0 ~ +8 %
HTS	according to optimum as given in ATIP	according to optimum as given in ATIP	according to optimum as given in ATIP	according to optimum as given in ATIP

Figure II-2 Definition of write strategies and β-ranges for media testing

Running OPC
During the recordings necessary for measurement of asymmetry variation over the disc (see chapter 0.14.9), using the recorder optical pick-up specified above, the reflected laser power must be kept at a constant level by using a 'Running OPC' procedure (see attachment XIII.13).

remark 3:
Implementation of "Write strategy" and "Recorder optical pick-up" in recorders.
In a recorder, the choice of beam profile and write strategy is free, however, they should be matched in such a way that all signals from a disc, recorded with the specific optical pick-up and write strategy, are within the specifications as mentioned in this chapter.
The above mentioned optical pick-ups (1, 2 and 3, each of them optimized for some specific measurements) are only specified for media testing.

II.4 The unrecorded disc

- The unrecorded CD-R disc fulfills the requirements as written in the DISC SPECIFICATION of the Red Book, **except for** the items mentioned in this chapter II.4.
- The paragraphs mentioned in this chapter II.4 **replace** the paragraphs with the same numbering of the Red Book.

	characteristic to be specified	requirement	remarks
2	**outer diameter**:		See chapter I.4.1 Definitions.
2.5.1	Disc unbalance U_d for 12 cm disc	< 2.5 g.mm	Corresponding Unbalance Force: F_U < 0.01 N at f_{rot} = 10 Hz
2.5.2	Disc unbalance U_d for 8 cm disc	< 1 g.mm	Corresponding Unbalance Force: F_U < 0.004 N at f_{rot} = 10 Hz
2.6	Outer rim height (ORH) at read-out side	$ORH + 0.7 * (t_{sub} - 1.2) \leq 0.10$ (mm)	See Figure XII-20 and Figure XII-21 (t_{sub} = substrate thickness at data area)
5	**Clamping area**		
5.4	Outer diameter of stacking ring area at read-out side	≤ 39.5 mm	See Figure XII-19
5.5	Outer diameter of stacking ring area at label side	≤ 44.0 mm	See Figure XII-19
8	**optical requirements:**		
8.6	Optical quality of the disc	wavefront distortion < 0.05λ (RMS value)	
9	**Information Area**		
9.1	Start time:	Start time is 1 minute (ATIP) before the start time of the Lead-in Area.	Corresponding start diameter: 44.4 +0.3/-0.4 mm.
9.2	Max outer diameter:	118 mm (78 mm)	(for the 8 cm CD-single)
14	**Sensitive layer**		
14.1	Polarity of modulation:	High to Low	In the Information Area
14.2	CNR for periodic effects in the range from 200-720 kHz:	≥ 47 dB	BW = 10 kHz
15	**Radial tracking signals**		
15.1	Normalized Push Pull Ratio	0.5 - 1.3	See attachment XIII.6
15.2	Max. variation of Push Pull amplitude	± 15 %	$\Delta PP / \langle PP \rangle$ over one disc
15.3	Radial noise	See Red Book: 15.2	
15.4	Radial Contrast	$RC_b > +0.05$	
16	**Tangential tracking signals**		
16.1	Locking frequency for the groove wobble	22.05 kHz	
16.2	Normalized wobble signal	0.035 - 0.060	See attachment XIII.7
16.3	CNR of wobble	> 35 dB	BW = 1 kHz

characteristic to be specified		requirement	remarks
17	**Time encoding**		
17.1	Wobble modulation:	ATIP	See chapter IV
17.2	ATER:	< 10 %	Averaged over any 10 seconds
17.3	Max number of successive erroneous ATIP frames:	3 frames	

characteristic to be specified	requirement	remarks
18 High speed recording conditions		
18.1 General recording strategy:	- In groove - laser modulation - nominal write strategy as defined in chapter II.3.3	LTS = Lowest Test Speed HTS = Highest Test Speed
18.2 Optimum write power of a disc: (at Lowest Test Speed: P_{WO} is P_W resulting in β = +4 %; at Highest Test Speed: P_{WO} is P_W resulting in β = centre value of β-range as given in ATIP)	P_{WO} determined by OPC.	β measured by read-only pick-up (2). See attachment XIII.3. An indicative value for P_{WO} is given in ATIP, see chapter IV.4.
18.3 Optimum write power range:	at LTS: $7 \le P_{WO} \le 14$ mW at HTS: 16x: $P_{WO} \le 32$ mW $P_{WO} + \Delta P \le 35$ mW 20x: $P_{WO} \le 37$ mW $P_{WO} + \Delta P \le 40$ mW 24x: $P_{WO} \le 41$ mW $P_{WO} + \Delta P \le 45$ mW 32x: $P_{WO} \le 48$ mW $P_{WO} + \Delta P \le 53$ mW 40x: $P_{WO} \le 54$ mW $P_{WO} + \Delta P \le 59$ mW 48x: $P_{WO} \le 60$ mW $P_{WO} + \Delta P \le 65$ mW $P_B \le 0.7$ mW	P_{WO} in central spot at defined recording speed (Nx) with indicated optimum write strategy and centre value of β-range P_B is bias power
18.4 Write power window of a disc, for $P_{low} < P_W < P_{high}$:	Disc must be recordable within specifications ([1])	at Lowest Test Speed: P_{low} is P_W resulting in β = 0%, P_{high} is P_W resulting in β = +8%; at Highest Test Speed: P_{low} is P_W resulting in β = lowest value of β-range as given in ATIP P_{high} is P_W resulting in β = highest value of β-range as given in ATIP; β measured by read-only pick-up (2).
		Over the Information area of the disc recorded at one CLV:
18.5a Maximum variation of P_{WO}	$\pm 0.05 * P_{WO}$	At β_{target}
18.5b Maximum variation of β	4% peak-to-peak	At P_{WO}
18.6 Wavelength of write spot:	$780 < \lambda < 792$ nm at $T_{ambient} = 23$ °C	Over the full temperature range the wavelength shall be as defined in attachment XIII.8
19 Local defects	See Red Book: 15.3 and attachment 7.	

[1] Note: In order to make good recordings, a CD-R drive shall control its writing power in such a way that it results in a β-value within the range specified for the disc (see attachment XIII.3).

characteristic to be specified		requirement	remarks
20	**Environment** (operating conditions during recording)	Disc must be recordable in all combinations given in Figure XII-4	See attachment XIII.4 and XIII.8
20.1	Temperature range	T = -5 to +55 ^{o}C	
20.2	Absolute humidity	0.5 to 30 g/m^3	
20.3	Relative humidity	5% to 95%	

II.5 The recorded disc

- The recorded CD-R disc fulfills all requirements as written in the chapter: "DISC SPECIFICATION" of the Red Book, unless otherwise stated in this chapter.
- The data on the disc has been recorded at the testing speeds defined in chapter IV.4.4.
- All parameters are specified for playback at 1x nominal CD speed, according to the Red Book. Measurements could be performed at other speeds with appropriate scaling of the results.

	characteristic to be specified	requirement	remarks
8.4	Reflection and double pass substrate transmission	$R_{top} \geq 0.60$	See attachment XIII.2 and Red Book 8.4
8.5	Max. variation of reflection	± 3%	$\Delta R_{top} / \langle R_{top} \rangle$ over one disc
9.3	Starting diameter of Lead-in Area	46 +0.2/-0.2 mm	Corresponding start time indicated in ATIP during the Lead-in area (see chapter IV.4)
14	**HF signal**		
14.5	Recorded time errors	no C2 uncorrectable errors at play back with 2.5 kHz PLL band width	See attachment XIII.9
14.6	Single frequency time errors:	The spectral components of the time errors should be below the values given in Figure XII-5.	For spectral components ≤ 4 kHz See attachment XIII.9
14.7	Jitter and effect length	see Red Book	
14.8	asymmetry	-15% ≤ asym ≤ +10 %	For all discs Asymmetry according to Red Book, measured by read-only pick-up (1)
14.9	Recommended max. variation of asymmetry	± 2 %	Δasym over one disc, measured by read-only pick-up (1). Recording made within one OPC (see attachment XIII.3) and using “Running OPC” (see attachment XIII.14) at one CLV
15	**Radial tracking signals**		
15.1	Push Pull magnitude	0.08 - 0.12	See attachment XIII.6 and XIII.8
15.4.1	Radial Contrast	$0.3 < RC_a < 0.6$	Over all discs
15.4.2	Max. variation of Radial Contrast	± 20 %	$\Delta RC_a / \langle RC_a \rangle$ Over one disc
17	**Tangential tracking signals**		
17.1	Locking frequency for the groove wobble	22.05 kHz	
17.2	CNR of wobble	> 26 dB	BW = 1 kHz
18	**Read conditions**		
18.1	Power of read spot	≤ 0.7 mW	CW, in central spot
18.2	Read stability	$> 10^6$ times successively read from a single track,	For T = 70 °C and P_{read} = 0.7 mW

characteristic to be specified	requirement	remarks
	the disc must remain within specification.	
18.3 Wavelength of read spot	$770 < \lambda < 830$ nm	See Red Book p 12 and attachment XIII.8

III. Requirements & recommendations for CD-recorders

III.1 Use of Disc Application Code, RID code, SCMS and Disc Identification

- All CD-recorders shall read the Disc Application Code and act accordingly to this.
  (see chapter IV.4.1.3)

- Consumer CD-recorders are only allowed to write on discs for unrestricted use.
  (see chapter IV.4.1.3)

- Consumer CD-recorders shall write their Recorder IDentification (RID) code in subcode Q-channel mode 3.
  (see chapter V.6.3.2)

- Consumer CD-recorders shall apply the Serial Copy Management System (SCMS).
  (see attachment XIII.12 and chapter V.6.3.1)

- Professional CD-recorders, able to write the CD-ROM and/or the CD-i Format, shall write their Recorder IDentification (RID) code in the main channel of the Table Of Contents Items in the PMA.
  (see chapter V.4.5)

- All CD-recorders (Consumer as well as Professional) shall write the Disc Identification Item in subcode Q-channel in the PMA (see chapter V.4.1 and V.4.3).

III.2 Use of Skip/Unskip features in audio discs

- It is recommended that all CD-recorders, able to write the CD-DA Format, react properly to all Time Intervals and Tracks that should be skipped as a result of the complete skip/unskip information in the PMA.
  (see chapter V.4.3)

- When an audio disc is finalized, it is recommended that all CD-recorders copy the skip information from the PMA to the TOC in the Lead-in Area. The number of “Skip Track” and “Skip Time Interval” Items that can be recorded in the Lead-in Area is limited to maximally 40 Time Intervals and 21 Tracks.
  (see chapter V.5)

IV. Pre-groove modulation, ATIP

By means of the groove wobble frequency (the carrier frequency), the CD-R disc contains motor control information and by means of ATIP (Absolute Time In Pre-groove, modulating the carrier frequency), the CD-R disc contains time-code information.
The ATIP time-code increases monotonically throughout the disc (see Figure XII-6) and shall extend at least till the time code = start of Additional Capacity & Lead-out Area + length of Additional Capacity & Lead-out Area + 30 seconds.

IV.1 General parameters

Disc	:	Radial track wobble
Carrier frequency	:	22.05 kHz
Analog modulation	:	FM
Digital modulation	:	Biphase-Mark
Synchronization	:	Biphase violation
Data bit-rate	:	3150 Bits/Sec
Frame length	:	42 bits (see Figure IV-1)
Frame frequency	:	75 Hz
Data contents	:	3 Bytes (Min Sec Frames, 1 Byte each)
Error protection	:	14 bits CRC

IV.2 FM modulation

Carrier frequency	:	22.05 kHz
Deviation	:	1 kHz ± 10 %
Oscillator output	:	Sinewave
Oscillator THD	:	< - 40 dB

IV.3 Frame format

The format of an ATIP frame is defined in Figure IV-1:

Nr of bits	4	8	8	8	14
Bit position	1234	111 56789012	11111112 34567890	22222222 12345678	23333333333444 90123456789012
Data	Sync	Minutes	Seconds	Frames	CRC remainder

Figure IV-1 Definition of the bits and fields in an ATIP frame

IV.3.1 Frame synchronization

For synchronization of the ATIP data the Biphase-Mark code rules are violated. The synchronization pattern used is 11101000 if the preceding cell = 0, or 00010111 if the preceding cell = 1.

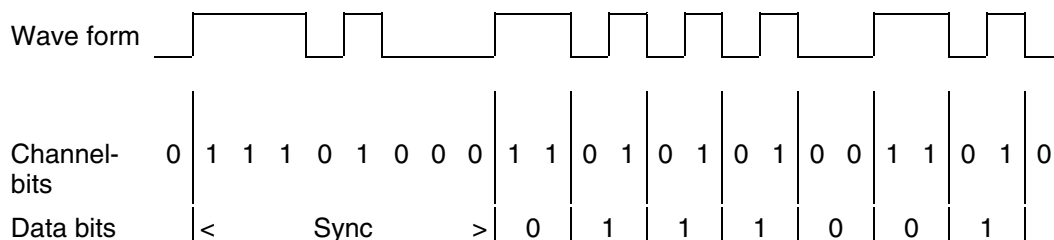



Figure IV-2 Example 1 of the synchronization of the ATIP frames

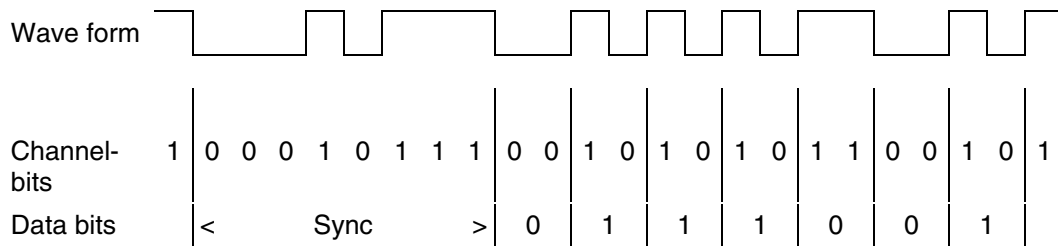
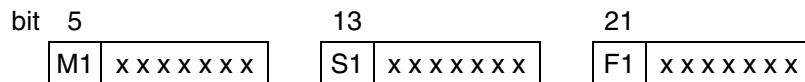



Figure IV-3 Example 2 of the synchronization of the ATIP frames

IV.4 Data format

The format of the ATIP time information is identical to the time encoding in Subcode-Q and in the CD-ROM header. The ATIP time information is represented in Binary Coded Decimal (BCD) with the most significant bit first as follows (see Figure IV-1):

Minutes : 2 digits BCD (M1..M4 and M5..M8), MSBit (M1) on position 5
Seconds : 2 digits BCD (S1..S4 and S5..S8), MSBit (S1) on position 13
Frames : 2 digits BCD (F1..F4 and F5..F8), MSBit (F1) on position 21

In addition to the normal timecode, in the Lead-in Area[2], the Additional Capacity & Lead-out Area (ACL) (see IV.4.3) and the eXtended Information Area (XIA) (see Figure XII-6 and Figure XII-7), extra CD-R information is encoded in the ATIP Minutes, Seconds and Frames bytes. This extra information is identified by specific combinations of the MSB's of the Minutes, Seconds and Frames bytes (bit 5, 13 and 21) as defined in Figure IV-2.
In the Program Area and in the PCA1, PCA2, PMA and eXtended ATIP Area (XAA) buffer only the normal timecode shall be encoded.

M1,S1,F1
= 000 or 100 : Time-code in Information area (see Figure XII-6)

= 101 : Special Information 1: information compliant with Volume 1, application code, disc type identification, in Lead-in Area (see chapter IV.4.1)
= 110 : Special Information 2: start time of Lead-in Area, in Lead-in Area (see chapter IV.4.2)
= 111 : Special Information 3: start time of Additional Capacity & Lead-out Area (SAL), in Lead-in Area (see chapter IV.4.3)
Note: start of Additional Capacity & Lead-out Area ≤ 79:59:74

= 001 : Additional Information 1: in XIA and ACL (see chapter IV.4.4)
= 010 : Additional Information 2: in XIA and ACL (see chapter IV.4.5)
= 011 : Additional Information 3: in XIA and ACL (see chapter IV.4.6)

Figure IV-4 Identification of the extra information in the Lead-in/ACL Areas

[2] In the context of the ATIP specifications, the term "Lead-in Area" has to be interpreted as the disc area between diameters 46 and 50 mm (so not the Lead-in Areas of 2nd or higher Sessions on a Multisession disc).

The sequence of successive ATIP frames in the Lead-in Area of a CD-R disc must be as indicated in Figure IV-5:

- One ATIP frame encoded with Special Information, followed by nine ATIP frames encoded with timecode information.
- Encoding of Special Information 1, 2 and 3 is mandatory in the Lead-in Area.
- All the encoded frames with Special Information must be used cyclic and must be successively repeated.
- The first ATIP frame with Special Information 1 in the Lead-in Area shall replace the timecode = Start time of Lead-in Area + 00:00:09 (**this offset of 9 frames identifies a disc according to this volume 2**).

frame number	frame contents
: N-1	normal timecode
N = SLI + 00:00:09	Special Information 1
N+1 : N+9	normal timecode
N+10	Special Information 2
N+11 : N+19	normal timecode
N+20	Special Information 3
N+21 : N+29	normal timecode
N+30	Special Information 1
N+31 : N+39	normal timecode
N+40	Special Information 2
N+41 : N+49	normal timecode
N+50	Special Information 3
N+51 :	normal timecode

Figure IV-5 Encoding of ATIP frames in the Lead-in Area
(SLI = Start Time of Lead-in Area)

The sequence of successive ATIP frames in the Additional Capacity & Lead-out Area of a CD-R disc must be as indicated in Figure IV-6:

- One ATIP frame encoded with Additional Information, followed by nine ATIP frames encoded with timecode information.
- Encoding of Additional Information 1, 2 and 3 is mandatory in the Additional Capacity & Lead-out Area.
- All the encoded frames with Additional Information must be used cyclic and must be successively repeated.
- The first ATIP frame with Additional Information 1 in the Additional Capacity & Lead-out Area shall replace the timecode = start time of Additional Capacity & Lead-out Area + length of Additional Capacity & Lead-out Area - 01:30:00. The encoding of the Additional Information shall end at start time of Additional Capacity & Lead-out Area + length of Additional Capacity & Lead-out Area - 00:30:00.

frame number	frame contents
: M-1	normal timecode
M = SAL + LAL - 01:30:00	Additional Information 1
M+1 : M+9	normal timecode
M+10	Additional Information 2
M+11 : M+19	normal timecode
M+20	Additional Information 3
M+21 : M+29	normal timecode
M+30	Additional Information 1
M+31 : M+39	normal timecode
M+40	Additional Information 2
M+41 : M+49	normal timecode
M+50	Additional Information 3
M+51 :	normal timecode

Figure IV-6 Encoding of ATIP frames in the Additional Capacity & Lead-out Area
(SAL = start time of Additional Capacity & Lead-out Area
LAL = length of Additional Capacity & Lead-out Area)

Extended ATIP Area
To increase the performance of recorders, the Additional Information is also stored in the eXtended ATIP Area (XAA). The start of the XAA is 01:00:00 ATIP before the start of the Lead-in Area. It ends 00:35:65 before the start of the Lead-in Area, which is the start of the PCA1. (see Figure XII-6 and Figure XII-7)
The first part of the XAA from 01:00:00 to 00:37:00 ATIP before the start of the Lead-in Area is called the eXtended Information Area (XIA) and contains all Additional Information.
The last part of the XAA from 00:37:00 to 00:35:65 ATIP before the start of the Lead-in Area is meant as a buffer zone and shall only contain normal time codes.

The sequence of successive ATIP frames in the eXtended Information Area of a CD-R disc must be as indicated in:

- One ATIP frame encoded with Additional Information, followed by nine ATIP frames encoded with timecode information.
- Encoding of Additional Information 1, 2 and 3 is mandatory in the XIA.
- All the encoded frames with Additional Information must be used cyclic and must be successively repeated.

frame number	frame contents
: K-1	normal timecode
K	Additional Information 1
K+1 : K+9	normal timecode
K+10	Additional Information 2
K+11 : K+19	normal timecode
K+20	Additional Information 3
K+21 : K+29	normal timecode
K+30	Additional Information 1
K+31 : K+39	normal timecode
K+40	Additional Information 2
K+41 : K+49	normal timecode
K+50	Additional Information 3
K+51 :	normal timecode

Figure IV-7 Encoding of ATIP frames in the eXtended Information Area

IV.4.1 Special Information 1 : M1,S1,F1 = 101

These 3 groups of 7 bits identify the disc type and specify several disc parameters (see Figure IV-8).

Figure IV-8 Combinations and definitions of the bits in Special Information 1

M1				S1		F1			
1	W1 W2 W3	X1	V1 V2 V3	0	U1 U2 U3 U4 U5 U6 U7	1	D1	B1 B2 B3	A1 A2 A3

W1..W3 : for compatibility with drives compliant with Volume 1
X1 : Reserved for future extensions (= 0)
V1..V3 : for compatibility with drives compliant with Volume 1

U1..U7 : Disc Application Code

D1 : Disc type
B1..B3 : for compatibility with drives compliant with Volume 1
A1..A3 : Presence of Additional Information

IV.4.1.1 Indicative Optimum Writing Power: W1..W3

To preserve compatibility with drives not compliant with this Volume 2, these bits shall be set to a value as defined in System Description Recordable Compact Disc Systems, part II: CD-R, volume 1: 1x/2x/4x.

W1..W3 = xxx : P_{ind} = see Volume 1

IV.4.1.2 Reference Speed: V1..V3

To preserve compatibility with drives not compliant with this Volume 2, these bits shall be set to a value as defined in System Description Recordable Compact Disc Systems, part II: CD-R, volume 1: 1x/2x/4x.

V1..V3 = 000 : Reference Speed = see Volume 1

IV.4.1.3 Disc Application Code: U1..U7

This code distinguishes between discs used for different applications. The two main application categories are: "Discs for unrestricted use", and "Discs for restricted use".
Within the category "Discs for restricted use", an additional encoding may be used for the identification of Special Disc Applications.

M1				S1		F1			
1	- - -	-	- - -	0	U1 U2 U3 U4 U5 U6 U7	1	-	- - -	- - -

U1 = 0 : disc for restricted use
- U2..U7 = 000000 : General Purpose disc
- U2..U7 = others : Identification Code for Special Purpose discs. Reserved for the encoding of Special Disc Applications.

U1 = 1 : only allowed for discs that are Full-range Volume 1 compliant (see chapter I.2)
- U2..U7 = 000000 : Disc for unrestricted use
- U2..U7 = others : Reserved

Discs for **restricted use** are meant to be used in Professional CD-recorders only.
Within this category the General Purpose discs can be used for any application.
Special Purpose discs, carrying a registered Identification Code, are meant for that registered application only.
Registration of the Identification Codes can be requested from Royal Philips Electronics (for detailed address information see: “Conditions of publication” in this document).

Discs for **unrestricted use** may be used in Consumer CD-recorders and in Professional CD-recorders.

IV.4.1.4 Disc type identification: D1

This single bit identifies the disc type.

M1				S1		F1			
1	- - -	-	- - -	0	- - - - - - -	1	D1	- - -	- - -

D1 = 0 : Recordable disc according to this specification
= 1 : Reserved (for CD-RW discs according to the Orange Book part III)

IV.4.1.5 Disc sub-type identification: B1..B3

To preserve compatibility with drives not compliant with this Volume 2, these bits shall be set to a value as defined in System Description Recordable Compact Disc Systems, part II: CD-R, volume 1: 1x/2x/4x.

B1..B3 = xxx : medium type = see Volume 1

IV.4.1.6 Additional Information 1, 2 or 3 present in the Lead-in Area: A1..A3

Each of these three bits indicates the presence of one of the Additional Information 1, 2 or 3 in the Lead-in area:

A1 indicates the presence of Additional Information 1 (0 = not present, 1 = present)
A2 indicates the presence of Additional Information 2 (0 = not present, 1 = present)
A3 indicates the presence of Additional Information 3 (0 = not present, 1 = present)

M1				S1		F1			
1	- - -	-	- - -	0	- - - - - - -	1	-	- - -	A1 A2 A3

A1..A3 = 000 : No Additional Information 1, 2 or 3 present in the ATIP in the Lead-in Area of CD-R discs
= others : Reserved (see chapter I.3)

IV.4.2 Special Information 2 : M1,S1,F1 = 110

This code specifies the start position of the Lead-in Area in ATIP timecode. On the disc, the MSBit of each timecode byte is replaced by the value of M1, S1 or F1 as specified in Figure IV-9.
At decoding the MSBit of each timecode byte has to be interpreted in the following way:

M1 to be replaced by M1 = 1,
S1 to be replaced by S1 = 0,
F1 to be replaced by F1 = 0.

Figure IV-9 Combinations and definitions of the bits in Special Information 2

M1		S1		F1	
1	M2 M3 M4 M5 M6 M7 M8	1	S2 S3 S4 S5 S6 S7 S8	0	F2 F3 F4 F5 F6 F7 F8

M1,M2..M8 S1,S2..S7 F1,F2..F7 : Minutes, Seconds, Frames

Example = 1001 0111 0100 1001 0000 0000
= 97:49:00 (example of decoded start time of Lead-in Area)

IV.4.3 Special Information 3 : M1,S1,F1 = 111

This code specifies the start position of the Additional Capacity & Lead-out Area in ATIP timecode.
Drives compliant with previous versions of this document will interpret this value as the last possible start position of the Lead-out Area.
Drives compliant with this version of this document can calculate the last possible start time of the Lead-out Area from this value, the length of Additional Capacity & Lead-out Area (LAL, see chapter IV.4.4) and the necessary Lead-out length (see V.7):

Last possible start time of Lead-out = SAL + LAL – actual Lead-out length

On the disc, the MSBit of each timecode byte is replaced by the value of M1, S1 or F1 as specified in Figure IV-10.
At decoding the MSBit of each timecode byte has to be interpreted in the following way:

M1 to be replaced by M1 = 0,
S1 to be replaced by S1 = 0,
F1 to be replaced by F1 = 0.

Figure IV-10 Combinations and definitions of the bits in Special Information 3

M1		S1		F1	
1	M2 M3 M4 M5 M6 M7 M8	1	S2 S3 S4 S5 S6 S7 S8	1	F2 F3 F4 F5 F6 F7 F8

M1,M2..M7 S1,S2..S7 F1,F2..F7 : Minutes, Seconds, Frames

Example = 0111 0000 0100 0101 0001 0101
= 70:45:15
(example of decoded start time of Additional Capacity & Lead-out area)

IV.4.4 Additional Information 1 : M1,S1,F1 = 001

These three groups of 7 bits specify high-speed recording parameters of the disc.

Figure IV-11 Combinations and definitions of the bits in Additional Information 1

M1			S1				F1		
0	L1 L2 L3	H1 H2 H3 H4	0	I1 I2 I3	Y1 Y2	C1 C2	1	N1 N2 N3	E1 E2 E3 E4

L1..L3 : Lowest Test Speed
H1..H4 : Highest Test Speed

I1..I3 : High-Speed subtype
Y1..Y2 : Reserved and set to zero
C1..C2 : Optimum β-range

N1..N3 : Optimum pulse length
E1..E4 : Length of Additional Capacity & Lead-out Area

IV.4.4.1 Lowest Test Speed: L1..L3

These 3 bits specify the lowest CLV recording speed at which this medium shall fulfill all requirements as defined in chapter II.3.

M1			S1				F1		
0	L1 L2 L3	- - - -	0	- - -	- -	- -	1	- - -	- - - -

L1..L3 = 010 : Lowest Test Speed = 4x nominal CD speed
others: Reserved

IV.4.4.2 Highest Test Speed: H1..H4

These 4 bits specify the highest CLV recording speed at which this medium shall fulfill all requirements as defined in chapter II.3. Highest test speed settings for 8 cm discs shall be limited to 32x, due to limitation of disc rotation frequency of approximately 10,000 rpm in most recording devices

M1			S1				F1		
0	- - -	H1 H2 H3 H4	0	- - -	- -	- -	1	- - -	- - - -

H1..H4 = 0110 : Highest Test Speed = 16x nominal CD speed
0111 : Highest Test Speed = 20x nominal CD speed
1000 : Highest Test Speed = 24x nominal CD speed
1001 : Highest Test Speed = 32x nominal CD speed
1010 : Highest Test Speed = 40x nominal CD speed, for 12 cm discs only
1011 : Highest Test Speed = 48x nominal CD speed, for 12 cm discs only

others: Reserved

IV.4.4.3 High-Speed subtype: I1..I3

These 3 bits are used to specify a sub-class within the Multi-Speed Recordable disc types.

M1			S1				F1		
0	- - -	- - - -	0	I1 I2 I3	- -	- -	1	- - -	- - - -

I1..I3 = 000 : CD-R Multi-Speed disc according to the ATIP definitions as specified in this document
others: Reserved for future types

The bits for the High-Speed subtype (I1..I3) and the bits for the speed indications (L1..L3 and H1..H4) will **keep the same meaning** in future disc types, although **new values can be added** to the existing settings.
All other bits in Additional Information 1, 2 and 3 can be assigned different meanings and/or different settings in future disc types. If such differences occur, a new High-Speed subtype will be assigned for such a disc.
Recorders not familiar with a certain High-Speed subtype, should not write on a disc with such an unknown subtype.

IV.4.4.4 Optimum β-range: C1..C2

These 2 bits specify the optimum β-range for the medium for recording at the Highest Test Speed as specified in H1..H4 (see attachment XIII.3).

M1			S1				F1		
0	- - -	- - - -	0	- - -	- -	C1 C2	1	- - -	- - - -

C1..C2 = 00	: optimum β-range =	–8 ~ 0 %	(target β = –4%)
01	:	–4 ~ +4 %	(target β = 0%)
10	:	0 ~ +8 %	(target β = +4%)
11	:	+4 ~ +12 %	(target β = +8%)

IV.4.4.5 Optimum pulse length: N1..N3

These 3 bits specify the optimum Write Pulse length for the medium for recording at the Highest Test Speed as specified in H1..H4 (see chapter II.3.3 and attachment XIII.3).

N1..N3 = 000 : (n–θ)T = (n–0)T
001 : (n–0.25)T
010 : (n–0.50)T
011 : (n–0.75)T
100 : (n+0.25)T
101 : (n+0.50)T
110 : (n+0.75)T
111 : (n+1.00)T

IV.4.4.6 Length of Additional Capacity & Lead-out Area : E1..E4

These 4 bits specify the Additional Capacity & Lead-out area length and the location of PCA2 by means of an offset relative to the Start Time of the Additional Capacity & Lead-out Area.

M1			S1				F1		
0	- - -	- - - -	0	- - -	- -	- -	1	- - -	E1 E2 E3 E4

E1..E4 = 0000 : 2 minutes
Others: reserved

IV.4.5 Additional Information 2 : M1,S1,F1 = 010

These three groups of 7 bits specify high-speed recording parameters of the disc.

Figure IV-12 Combinations and definitions of the bits in Additional Information 2

M1			S1				F1	
0	W4 W5 W6	W7 W8 W9 W10	1	P1 P2 P3	T1 T2	Y1 Y2	0	Z1 Z2 Z3 Z4 Z5 Z6 Z7

W4..W6 : Indicative Optimum Writing Power at Lowest Test Speed
W7..W10 : Indicative Optimum Writing Power at Highest Test Speed

P1..P3 : Power boost for I_3 pits
T1..T2 : Pulse length correction after I_3 lands
Y1..Y2 : Reserved and set to zero

Z1..Z7 : Reserved and set to zero

IV.4.5.1 Indicative Optimum Writing Power at Lowest Test Speed: W4..W6 for discs with High Speed Subtype I1..I3 = 000

W4..W6 specify an indicative value P_{ind} for P_{WO} (see attachment XIII.3). This P_{ind} value is given for a laser wavelength of 786 nm and T = 23 °C at the Lowest Test Speed as specified in L1..L3 (see chapter IV.4.4.1).
The actual optimum P_{WO} depends on the recording speed and on parameters of the optical recorder pickup unit. Therefore the encoded value P_{ind} can only be used as a starting value for the determination of the optimum value of P_{WO} by an Optimum Power Control procedure, as described in attachment XIII.3.

M1				S1				F1	
0	W4 W5 W6	- - -	-	1	- - -	- -	- -	0	- - - - - - -

W4..W6 =		Pind =
000	:	7 mW
001	:	8 mW
010	:	9 mW
011	:	10 mW
100	:	11 mW
101	:	12 mW
110	:	13 mW
111	:	14 mW

IV.4.5.2 Indicative Optimum Writing Power at Highest Test Speed: W7..W10 for discs with High Speed Subtype I1..I3 = 000

W7..W10 specify an indicative value P_{ind} for P_{WO} (see attachment XIII.3). This P_{ind} value is given for a laser wavelength of 786 nm and T = 23 ^{o}C at the Highest Test Speed as specified in H1..H4 (see chapter IV.4.4.2).
The actual optimum P_{WO} depends on the recording speed and on parameters of the optical recorder pickup unit. Therefore the encoded value P_{ind} can only be used as a starting value for the determination of the optimum value of P_{WO} by an Optimum Power Control procedure, as described in attachment XIII.3.

M1					S1					F1	
0	- - -	W7 W8 W9 W10			1	- - -	- -	- -		0	- - - - - - - -

W7..W10 =		Pind =
0000	:	16 mW
0001	:	18 mW
0010	:	20 mW
0011	:	22 mW
0100	:	24 mW
0101	:	26 mW
0110	:	28 mW
0111	:	30 mW
1000	:	32 mW
1001	:	34 mW
1010	:	36 mW
1011	:	38 mW
1100	:	41 mW
1101	:	44 mW
1110	:	47 mW
1111	:	50 mW

IV.4.5.3 Power Boost for I_3 pits: P1..P3

These 3 bits specify the optimum ΔP for the I_3 Write Pulse for recording at the Highest Test Speed as specified in H1..H4 (see chapter II.3.3 and attachment XIII.3).

M1					S1					F1	
0	- - -	- - - -	-		1	P1 P2 P3	- -	- -		0	- - - - - - - -

P1..P3 =		ΔP =
000	:	0 %
001	:	2 %
010	:	4 %
011	:	6 %
100	:	8 %
101	:	10 %
110	:	12 %
111	:	14 %

IV.4.5.4 Pulse length correction after I_3 lands: T1..T2

These 2 bits specify the optimum ΔT for each Write Pulse after an I_3 Land for recording at the Highest Test Speed as specified in H1..H4 (see chapter II.3.3 and attachment XIII.3).

M1								S1								F1							
0	-	-	-	-	-	-	-	1	-	-	-	T1	T2	-	-	0	-	-	-	-	-	-	-

T1..T2	=		ΔT =
	00	:	0 T
	01	:	1/16 T
	10	:	2/16 T
	11	:	3/16 T

IV.4.6 Additional Information 3 : M1,S1,F1 = 011

These three groups of 7 bits contain codes that uniquely identify each media.

Figure IV-13 Combinations and definitions of the bits in Additional Information 3

M1			S1		F1		
0	J1 J2	Q1 Q2 Q3 Q4 Q5	1	Q6 Q7 Q8 Q9 Q10 Q11 Q12	1	Q13 Q14 Q15 Q16	R1 R2 R3

J1..J2 : Media technology type
Q1..Q12 : Media IDentification (MID) code first part
Q13..Q16 : Media IDentification (MID) code second part
R1..R3 : Product revision number

IV.4.6.1 Media technology type: J1..J2

These 2 bits specify the type of technology of the recordable layer on the disc.

M1			S1		F1		
0	J1 J2	- - - - -	1	- - - - - - -	1	- - - -	- - -

J1..J2 = 00 : Cyanine or comparable type recording layer
01 : Phtalo-cyanine or comparable type recording layer
10 : Reserved
11 : Other type of recording layer

Media not behaving in accordance with type 00 (Cyanine) or type 01 (Phtalo-cyanine) should be identified as type 11 (Other). The type is to be determined by the media manufacturer.

IV.4.6.2 Media Identification (MID) code: Q1..Q16

These 16 bits contain a code that uniquely identify the Disc Manufacturer and the type of product.

M1			S1		F1		
0	- -	Q1 Q2 Q3 Q4 Q5	1	Q6 Q7 Q8 Q9 Q10 Q11 Q12	1	Q13 Q14 Q15 Q16	- - -

Q1..Q12 The MID code first part, represented by Q1..Q12, shall be issued and registered by Royal Philips Electronics.
If needed, a manufacturer can request additional codes.
Q13..Q16 The MID code second part can be used by the Disc Manufacturer to identify 16 (different) disc types in his product range.

IV.4.6.3 Product revision number: R1..R3

These 3 bits can be used to identify different versions of the same type of product.

R1..R3 The Product revision number, represented by R1..R3, can be chosen freely by the Disc Manufacturer. However all discs with the same MID code Q1..Q16, although with different Product revision numbers, must have the same recording properties (only minor differences are allowed: Product revision numbers shall be irrelevant for recorders).

IV.5 Error detection

The error detection method uses a 14 bits CRC on Minutes, Seconds and Frames. The CRC codeword must be divisible by the check polynomial. The most significant bit of the CRC codeword is bit 5, the least significant bit is bit 42 of the ATIP frame. The CRC parity bits (bit 29 .. 42) are inverted on the disc.

The check polynomial is :
$P(X) = X^{14} + X^{12} + X^{10} + X^{7} + X^{4} + X^{2} + 1$

IV.6 Bit rate

Bit rate = nr of addresses/sec ∗ nr of bits/address
= 75 ∗ 42
= 3150 bits/sec.

The bit rate is 1/7 of the 22.05 kHz wobble frequency. Both the 22.05 kHz wobble and 6.3 kHz biphase clock frequencies are derived from the same 44.1 kHz source.

IV.7 ATIP encoder

The block diagram of the ATIP encoder is :

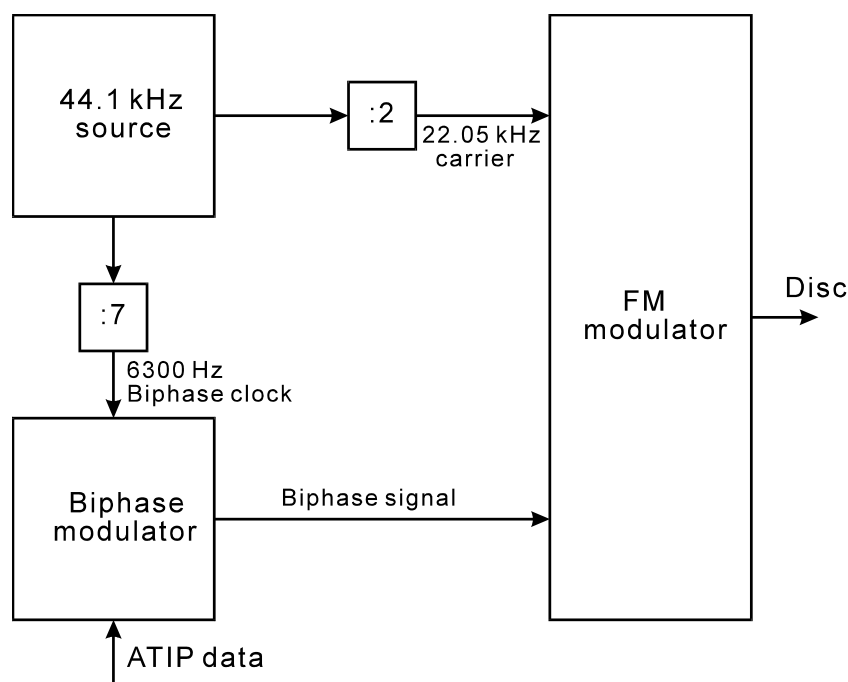



Figure IV-14 Block diagram of a typical ATIP encoder

V. Data organization

- The encoding rules for CD-Audio Tracks are as given in the Red Book unless specified otherwise in this document.
- The encoding rules for Data Tracks are as given in the Yellow Book or the Green Book unless specified otherwise in this document. As this chapter V is written as an extension to the Red Book, some specification items must be replaced by the concerned items from the Yellow Book or Green Book, if recordings according to these books are made.
- Recording the complete disc (including Lead-in and Lead-out) in an uninterrupted single writing action is defined as **Uninterrupted Writing** or **Disc At Once** (DAO) recording. For an Uninterrupted written disc, the data organization must be as specified in the Red Book, the Yellow Book or the Green Book, whichever is appropriate, except for Subcode-Q mode 5 (see chapter V.5).
- The Information Area of a CD-R disc is divided into the following areas (see chapter I.4.2 and Figure XII-1, Figure XII-2, Figure XII-3, Figure XII-8 and Figure XII-18):
  1: Power Calibration Areas
  2: Program Memory Area
  3: One or more Sessions, each consisting of:
     - Lead-in Area
     - Program / Recordable Area
     - Lead-out Area

In this chapter the structure of the PCA1, PCA2, the PMA and a Session will be described. The structure of a Multisession disc is defined in chapter XI.

V.1 ATIP synchronization rule

Over the entire disc the allowed tolerance between the position of the ATIP sync and the Subcode sync is 0 ± 2 EFM frames.
The position of an ATIP-sync is defined as the position where a sync can be determined as a sync pattern; this means directly after the physical sync pattern on the disc.
The position of a Subcode-sync is defined as the start position of the physical sync pattern on the disc (see Figure XII-10).
The recorded Q-channel Absolute Time on any position of the disc is exactly synchronized with the ATIP time at that position.

V.2 Linking rules

Recording the disc in several distinct writing actions (e.g. at different times, on different recorders) is defined as **Incremental Writing**. In case of Incremental Writing the linking rules must be taken into account.

V.2.1 General Linking Rules

(see Figure XII-11)
The Link Position is the physical location on the disc where the recording of EFM signals is allowed to start and stop.
The nominal Link Position is 26 EFM frames after the start of a Subcode-sync pattern.
No gap between the recordings is allowed. Between recordings, a maximum overwrite of 12 EFM frames is allowed.
The start and stop positions of the recordings must be in the following range:
- Start position: 26 +0/-4 EFM frames after the start of the encoder Subcode-sync.
- Stop position: 26 +4/-0 EFM frames after the start of the encoder Subcode-sync.

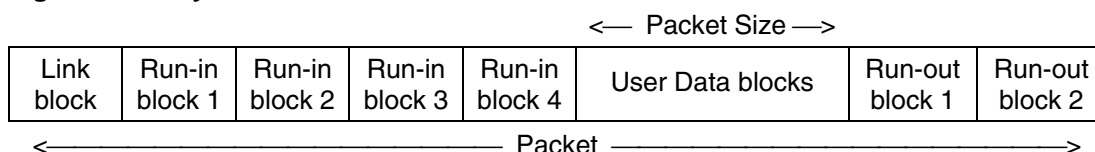
In the Power Calibration Area different linking rules are applied (see chapter V.3).

V.2.2 Audio Linking

In the case of audio recording, at least 1 Interleave Length (about 15 milliseconds) of digital silence is recommended at the beginning and at the end of an EFM recording sequence (see Figure XII-12).

V.2.3 Data Linking

In the case of data recording, the EFM recording sequence shall start and end with Link, Run-in and Run-out blocks. One set of recorded Link, Run-in, User Data and Run-out blocks is called a Packet. The number of User Data blocks in a Packet is called the Packet Size.

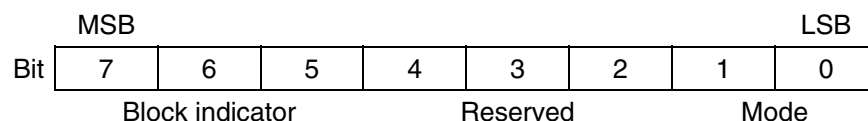
Figure V-1 Layout of a Packet

The start of a Block sync (before CIRC/EFM encoding with a minimum delay encoder, see Yellow Book page 33) is within -10 and +36 EFM frames after the start of a Subcode sync (see Figure XII-10).

Note: When the start of the Block sync is delayed more than about 16 EFM frames relative to the Subcode sync, then the last data bytes of Run-out block 1 can be expected to be flagged "uncorrectable" by the CIRC decoder due to the Interleave Length.
The first data bytes of Run-out block 1, containing the Block Header, can be expected to be correct when the delay is within the specified limits.

The Link block is the block that nominally contains the Link Position as specified in chapter V.2.1. Each EFM recording within a Data Track must be recorded as one Packet, so each recording must start with a (partial) Link block followed by four Run-in blocks, minimum one User Data block and two Run-out blocks and shall be closed with the first part of the next Link block (see Figure XII-12).

Each Data Track must contain minimum one Packet with user Data. At the beginning and at the end of the Lead-in and Lead-out Areas, the recording of Run-in and Run-out blocks is optional.

Identification of the Link, Run-in, User Data and Run-out blocks is in the Mode byte (in the Block Header, see Yellow Book page 101). The lay-out of this Mode byte is given in Figure V-2 (bit 7 is first bit and MSB).

Figure V-2 Layout of the Mode byte

bit 7..5 : Block indicators
= 000 : User Data block
= 001 : Fourth Run-in block
= 010 : Third Run-in block
= 011 : Second Run-in block
= 100 : First Run-in block
= 101 : Link block: physical linking of EFM data according to the General Linking Rules in chapter V.2.1
= 110 : Second Run-out block
= 111 : First Run-out block

bit 4..2 = 000 : Reserved

bit 1..0 : Yellow Book Mode indication
= 00 : mode 0
= 01 : mode 1
= 10 : mode 2
= 11 : Reserved

V.2.3.1 Use of RID code in data applications

(optional, see also chapter V.4.5)
For Consumer CD-recorders the use of the RID code (Recorder IDentification code) in mode 3 of the Subcode Q-channel is mandatory in audio recordings (see chapter V.6.3.2). Professional CD-recorders can store their RID code in the User Data field of all Run-in and Run-out blocks at each data recording action. The content of the User Data field of the Run-in and Run-out Blocks containing the RID code is defined in Figure V-3.

User Data byte	Contents
0..4	RID code identifier “RID01”
5..7	Reserved (00h)
8 9 10	RID Manufacturer Code (I_1) ‘A’..Z’ RID Manufacturer Code (I_2) ‘A’..’Z’ RID Manufacturer Code (I_3) ‘A’..’Z’
11..15	Reserved (00h)
16 17 18 19	RID Recorder Type Code (I_4) ‘A’..’Z’ RID Recorder Type Code (I_5) ‘A’..’Z’ RID Recorder Type Code (I_6) ‘0’..’9’ RID Recorder Type Code (I_7) ‘0’..’9’
20..23	Reserved (00h)
24 25 26	RID Recorder Unique Number (0, I_8) RID Recorder Unique Number (I_9, I_{10}) RID Recorder Unique Number (I_{11}, I_{12})
27..31	Reserved (00h)
32..63	Manufacturer name
64..79	Supplementary Recorder Type Code
80..95	Supplementary Recorder Unique Number
96..255	Reserved (00h)
256..1023	Manufacturer specific
1024..2047	Reserved (00h)

Figure V-3 Definition of the User Data bytes in the Run-in and Run-out blocks

The RID code for data applications is defined in a consistent way with the RID code for audio applications (see chapter V.6.3.2).

byte 0..4 = RID code identifier:
This field, coded in ISO 646 with the characters “RID01”, indicates that this block contains RID code information.

byte 5..7 = Reserved

byte 8..10 = RID Manufacturer Code (I_1..I_3):
A 3-character code unique for each recorder manufacturer, coded in ISO 646. This code shall be issued and registered by Royal Philips Electronics (see also chapter V.6.3.2.1)

byte 11..15 = Reserved

byte 16..19 = RID Recorder Type Code ($I_4..I_7$):
A 4-character code unique for each recorder model, coded in ISO 646. This code is defined by the recorder manufacturer.

byte 20..23 = Reserved

byte 24..26 = RID Recorder Unique Number (0, $I_8..I_{12}$):
A unique 20-bit binary serial number for each single recorder unit. The first 4 bits of byte 24 are set to “0000”. Each following 4 bits represent one of $I_8..I_{12}$ The fifth bit of byte 24, corresponding to the first bit of I_8, is the msb of the number; the last bit of byte 26, corresponding to the last bit of I_{12}, is the lsb of the number.

byte 27..31 = Reserved

byte 32..63 = Manufacturer name:
This ISO 646 coded field optionally contains the full name of the recorder manufacturer. If not used this field shall be filled with 00h.

byte 64..79 = Supplementary Recorder Type Code:
The contents of this ISO 646 coded field is defined by the recorder manufacturer. If not used this field shall be filled with 00h.

byte 80..95 = Supplementary Recorder Unique Number:
The contents of this ISO 646 coded field is defined by the recorder manufacturer. If not used this field shall be filled with 00h.

byte 96..255 = Reserved

byte 256..1023 = Manufacturer specific:
Information to be defined by the recorder manufacturer.

byte 1024..2047= Reserved

V.3 Power Calibration Areas

The Power Calibration Areas (PCA1 and PCA2) are reserved to determine the correct writing power for a disc. Each PCA is divided into two areas (see Figure XII-8):

1: The **Test Area**, in which tests with Random EFM data can be performed to obtain the correct writing power for a disc.

2: The **Count Area**, where can be read which part of the Test Area can be used.

Both test and count areas of the PCA1 and PCA2 are divided into partitions, which must be used in sequential order, starting from partition number one. To extend the maximum number of power calibrations, each partition in the Test Area can be optionally divided into subpartitions (see attachment XIII.14).
The PCA2 is located immediately after the Additional Capacity & Lead-out Area of the disc. (see Figure XII-6). For 12 cm discs the PCA2 shall be located completely inside diameter 117.0 mm.
Care shall be taken that the recording characteristics of PCA1 and PCA2 are identical to the recording characteristics of the program area within the tolerances as specified in Chapter II.

V.3.1 Test Areas

PCA1:

The Test Area1 is reserved for performing OPC (Optimum Power Control) procedures as described in attachment XIII.3. The start time is 00:35:65 ATIP before the start of the Lead-in Area. It ends 00:15:05 before the start of the Lead-in Area, which is the start of the Count Area1. The start of the Lead-in Area is encoded in ATIP during the Lead-in Area (see chapter IV.4).
The Test Area1 is divided into 100 numbered partitions. Partition numbering increases from 1 to 100 from outside to inside disc diameter (backwards numbering from the end of the Test Area1to the start, see Figure XII-8).
Each partition is 15 ATIP frames long (15/75 seconds). Each partition number p starts at a fixed ATIP time, and ends at the start of partition (p-1). Partition p starts ($p*15 + 1160$) ATIP frames before the start of the Lead-in Area (see Figure XII-8).
The Test Area1 starts and ends with 30 reserved ATIP frames, to facilitate the search for the start of partition 100 of the Test Area1 and the start of the Count Area1.
The nominal Link Position for both starting and stopping has to be 0 ± 2 EFM frames after the end of the ATIP-sync (this is different from the General Linking Rules).

PCA2:

The Test Area 2 is reserved for performing OPC (Optimum Power Control) procedures as described in attachment XIII.3. The start time is SAL+LAL. It ends at SAL+LAL+00:20:60, which is the start of the Count Area2. The Test Area2 is also divided into 100 numbered partitions. Partition numbering increases from 1 to 100 from outside to inside disc diameter (backwards numbering from the end of the Test Area2 to the start, see Figure XII-9).
Each partition is 15 ATIP frames long (15/75 seconds). Each partition number p starts at a fixed ATIP time, and ends at the start of partition (p-1).
Partition p starts (1530 - p*15) ATIP frames after the SAL+LAL (see Figure XII-9).
The Test Area2 starts and ends with 30 reserved ATIP frames, to facilitate the search for the start of partition 100 of the Test Area2 and the start of the Count Area2.
The nominal Link Position for both starting and stopping has to be 0 ± 2 EFM frames after the end of the ATIP-sync (this is different from the General Linking Rules).

V.3.2 Count Areas

The Count Areas provide a reliable and fast detection of the first usable, free partition in the Test Areas.

Count Area1:

The Count Area1 starts 00:15:05 ATIP before the start of the Lead-in Area, which is the end of the Test Area1. It ends 00:13:25 ATIP before the start of the Lead-in Area, which is the start of the Program Memory Area (see Figure XII-8).
The Count Area1 is divided into 100 numbered partitions. Partition numbering increases from 1 to 100 from outside to inside disc diameter. Each partition in the Count Area1 is 1 ATIP frame long (1/75 seconds). Each partition p starts at a fixed ATIP time and ends at the start of partition number (p-1). Partition p starts ($p*1 + 1030$) ATIP frames before the start of the Lead-in Area (see Figure XII-8).
The Count Area1 ends with 30 reserved ATIP frames, to facilitate the search for the start of the Program Memory Area.
Partition p in the Count Area1 must be recorded with EFM, after partition p in the Test Area1 has been used for performing an OPC procedure.
By counting the number of empty partitions E in the Count Area1 (from the start up to the first recorded partition), the first usable partition U in the Test Area1 is determined by U=101-E.
In the Count Area1, the recording of EFM data (random EFM allowed) has to be as specified for the rest of the Information Area, except for the Nominal Link Position as described in chapter V.2.1. In the Count Area1, the Link Position for both starting and stopping has to be 0 ± 2 EFM frames after the end of the ATIP-sync.

Count Area2:

The Count Area2 starts at SAL + LAL + 00:20:60, which is the end of the Test Area2. It ends at SAL + LAL + 00:22:40. The Count Area2 is divided into 100 numbered partitions. Partition numbering increases from 1 to 100 from outside to inside disc diameter. Each partition in the Count Area2 is 1 ATIP frame long (1/75 seconds). Each partition p starts at a fixed ATIP time and ends at the start of partition number (p-1). Partition p starts ($1660 - p*1$) ATIP frames after the SAL + LAL (see Figure XII-9).
The Count Area2 ends with 30 reserved ATIP frames. Partition p in the Count Area2 must be recorded with EFM, after partition p in the Test Area2 has been used for performing an OPC procedure.
By counting the number of empty partitions E in the Count Area2 (from the start up to the first recorded partition), the first usable partition U in the Test Area2 is determined by U=101-E.
In the Count Area2, the recording of EFM data (random EFM allowed) has to be as specified for the rest of the Information Area, except for the Nominal Link Position as described in chapter V.2.1. In the Count Area2, the Link Position for both starting and stopping has to be 0 ± 2 EFM frames after the end of the ATIP-sync.

V.4 Program Memory Area

The Program Memory Area (PMA) starts at 00:13:25 ATIP before the start of the Lead-in Area. It ends at the start time of the Lead-in Area, which is encoded in ATIP during the Lead-in Area (see chapter IV.4).
As long as the Lead-in Area is in the unrecorded state, the PMA is used for intermediate storage. The PMA contains information about the recordings on the disc, this information is encoded in the Subcode Q-channel.
The use of the Program Memory Area is mandatory, except for Uninterrupted Written (DAO) discs, in which case it is recommended not to use the PMA. If the disc leaves the recorder then the PMA must contain the actual status of the complete contents of the disc.

V.4.1 Contents

The PMA can contain the following types of information:

1: Track numbers with their start and stop time. This is the table of contents for the partially recorded disc. The Track numbers of all Tracks (including Reserved Tracks, see chapter V.4.1.1) in the PMA must be contiguous and increment by one.
2: Disc identification: A unique, 24-bit binary number shall be recorded in the disc to identify each disc.
3: Skip/Unskip information (optional). It is possible to indicate that an entire Track or a part of a recorded Track (a time interval) should be skipped during play back of the disc. Unskip means that this instruction to skip is canceled. The Skip feature is defined for Audio Sessions only. A Session is an Audio Session if no Data Tracks are present in that Session.
4: The RID code in the User Data field of the blocks for Table Of Contents Items.

Examples of PMAs are given in Figure XII-13 and Figure XII-14.

V.4.1.1 Reserved Track

A Reserved Track is a Data Track, which is not yet completely recorded, but the start and the stop time of the Track are already recorded in the PMA. If a Reserved Track is not the first Track in the Program Area then the Reserved Track shall be of the same mode as the preceding Track (see attachment XIII.10). Before the disc or the Session (see chapter XI) is finalized, all the Reserved Tracks in the finalized part of the disc must be recorded.
If a Reserved Track is not the first Track in the Program Area and no data is recorded in this Track, then the difference between the start time of the Reserved Track and the stop time of the previous Track must be 00:02:00.
If a Reserved Track is meant to be written incrementally with fixed packets, then the Track length and the Packet size must be determined in such a way that an integer number of Packets will fit in the Track (see Figure XIII-10); this means that the start and stop time of the Track must be according to the following equation:

$$\text{Stop time} - \text{Start time} = \text{Number of packets} * (\text{Packet size} + 7) - 5$$

The start time of a Track shall be equal to the Header Address belonging to the first User Data block of the Track (see chapter V.6.5.1). The stop time of a Track shall be equal to the Header Address belonging to the (partial) Link block at the end of the last Packet (see Figure XII-12) to be recorded in the Track.

V.4.1.2 Incomplete Track

An Incomplete Track is a Data Track in which a series of incrementally written data Packets can be recorded. The Start- and the Stop-time of the Incomplete Track are not yet recorded in the PMA. At the start of the Incomplete Track a Pre-gap (see chapter V.6.5.1) containing Track Descriptor Blocks (see chapter V.6.5.2) must be recorded.
It is allowed to have maximum one Incomplete Track on a disc. The Incomplete Track is the last Track in the last Session on the disc. The Track Number of the Incomplete Track is equal to one, or equal to the Track Number of the last Track recorded in the PMA plus one.

V.4.2 Recording sequence

A recording action in the PMA must always be performed in a multiple of ten Subcode frames. Within such a **Unity** of ten frames, the successive frames are labeled 0 (first frame) to 9 (last frame) in the ZERO byte of the Subcode-Q channel. In the recorded part of the PMA, this ZERO byte must continuously repeat this cyclic counting from 0 to 9.
The specific contents, the information within a Subcode frame, is called an **Item**. An Item is repeated five times in five successive Subcode frames. As a Unity consists of ten Subcode frames, these five successive repetitions of an Item are labeled 0 to 4 or 5 to 9. When an uneven number of Items must be recorded, the last of these Items is repeated ten times instead of the usual five times, because recording must always be done in multiples of ten Subcode frames. In this case, the ten successive repetitions are labeled 0 to 9 in the ZERO byte.

The first Item in a PMA sequence is recorded at the start time of the PMA. Items specifying the start-, and stop times of Tracks (TOC Items) have to appear in order of increasing Track numbers. Other valid PMA Items can appear anywhere in the PMA sequence.

V.4.3 The Subcode-Q channel

The encoding of the Subcode-Q channel frame is: (see Figure XII-13 and Figure XII-14)

Figure V-4 Encoding in the PMA of a Subcode-Q frame

S0,S1	CONTR	ADR	TNO	POINT	MIN	SEC	FRAME	ZERO	PMIN	PSEC	PFRAME	CRC

S0, S1 : The coding rules are according to the Red Book, page 40.

CONTROL : see CONTROL in chapter V.6.3.1, except for bit 1 (the Copy Bit). If ADR=1 (TOC Item) then the Copy Bit is '1' (no copyright) only if the Copy Bit is '1' in all parts of the Track specified by POINT.
Note: The correct copyright status of a Track must always be checked in the Program Area. In case of doubt about the final copyright status of a Track (e.g. in case of a Reserved Track) the Copy bit in the PMA should be set to ‘0’ (copyright protected). This can be different from the final Copy bit setting in the subcode-Q channel in the Lead-in Area.

TNO = 00

ZERO = 00..09: A counter which labels the successive frames in a Unity of ten Subcode frames. The first frame is labeled 0, the last is 9.

CRC : see Red Book page 41: 16 bit CRC on Control, ADR and Q-data (MSB first). On the disc the parity bits are inverted. The remainder have to be checked at zero. The check polynomial is: $P(X) = X^{16} + X^{12} + X^5 + 1$

ADR : The value in ADR determines what kind of information is in the Item (see chapter V.4.1).

ADR = 1 : "Table Of Contents" Items: The Track numbers and start-, and stop times of all Tracks.
a) POINT=01..99: the value of POINT = n, when the Track has Track number n.
b) The value of PMIN, PSEC and PFRAME gives the start time of the Track, pointed to by POINT.
c) The value of MIN, SEC, FRAME gives the stop time of the Track pointed to by POINT.

ADR = 2 : The "Disc Identification" Item. The use of this Item is mandatory. In this Item a statistically unique 24-bit binary number is recorded which can be used for the identification of each disc. Usually this Item is recorded only once in the PMA. If the indicated format of the Data Sessions on the disc has to be adapted, e.g. according to a new Session, the Disc Identification Item can be written again, with the same 24-bit Disc Identification number and a different format indication in PSEC.
a) MIN, SEC, FRAME each contain a binary encoded 8-bit number. The 24 bits together are the Disc Identification. This 24-bit number shall be determined at random for each disc.
b) PSEC specifies the format of the Data Sessions on the disc (all Data Sessions on a disc must be of the same format).
The allowed values (hex) are:
00 : CD-DA or CD-ROM Sessions
10 : CD-i Sessions
20 : CD-ROM XA Sessions
All other values are reserved.
c) POINT, PMIN, PFRAME are reserved and set to zero.

Example: If the first Session on a disc is an Audio Session, then after writing this session, the value of PSEC must have the value 00. If later a CD-ROM XA Session is added to the same disc, a new Disc Identification Item must be recorded with PSEC set to 20.

ADR = 3 : "Skip Track" Item. The use of this Item is optional for Audio Sessions (not allowed in Data Sessions). In each of these Items maximally six Track numbers can be noted which have to be skipped during play back.
If not used, ADR=3 is not present.
a) POINT=01..21: The value of POINT is J, when this is the J^{th} "Skip Track" assignment that is noted in the PMA.
b) MIN, SEC, FRAME, PMIN, PSEC, PFRAME can each contain a Track number of a Track which has to be skipped during play back of the disc. If less than six Tracks are noted, the remaining bytes have to be set to zero.

ADR = 4 : "Unskip Track" Items. The use of this Item is optional. These Items are used to cancel a previously given 'Skip track' assignment.
If not used, ADR=4 is not present.
a) POINT=01..21: The value of POINT is K, when this is the K^{th} "Unskip Track" assignment that is noted in the PMA.
b) MIN, SEC, FRAME, PMIN, PSEC, PFRAME each can contain a track number of a track which is noted previously in a "Skip track" Item. This track will now be played back normally again. If less than six tracks are noted, the remaining bytes have to be set zero.

ADR = 5 : "Skip Time Interval" Items. The use of this Item is optional for Audio Sessions (not allowed in Data Sessions). These Items are used to indicate that a time interval in the Program Area of the disc has to be skipped during play back.
If not used, ADR=5 is not present.

a) POINT=01..40: The value of POINT is M, when this is the M^{th} "Skip Time Interval" assignment that is noted in the PMA.
b) The value of PMIN, PSEC, PFRAME gives the start time of the "Skip Time Interval" number M, pointed to by POINT.
c) The value of MIN, SEC, FRAME gives the stop time of the "Skip Time Interval" number M, pointed to by POINT.

ADR = 6 : "Unskip Time Interval" Items. The use of this Item is optional. These Items are used to cancel a previously given "Skip Time Interval" assignment.
If not used, ADR=6 is not present.

a) POINT=01..40: The value of POINT is N, when this is the N^{th} "Unskip Time Interval" assignment that is noted in the PMA.
b) MIN, SEC, FRAME, PMIN, PSEC, PFRAME each contain a number M of a time interval which is noted previously as "Skip Time Interval" number M (see ADR=5). This time interval will now be played back normally again. If less than six numbers are noted, the remaining bytes have to be set to zero.

ADR = 7..F : Reserved.

Remark: In the PMA, the net result of skipped and unskipped Tracks must never exceed 21.

V.4.4 P, R..W Subcode channels

In the PMA the Subcode channels P, R..W are reserved, and set to zero.

V.4.5 RID code in the main channel

Professional CD-recorders, able to write the CD-ROM and/or the CD-i Format, shall write their RID code (see chapters V.2.3.1 and V.6.3.2.1) in the main channel of the Table Of Contents Items (subcode mode 1) in the PMA, whenever they record such an item. This RID code shall be block encoded with a User Data field as defined in Figure V-5.

If the disc is an Uninterrupted written (DAO) disc, without a Table Of Contents recorded in the PMA, then the RID code shall be recorded in the main channel of the last Unity of ten frames (see chapter V.4.2) at the end of the Program Memory Area (just before the start of the Lead-in Area). This RID code shall be block encoded with a User Data field as defined in Figure V-5.
All subcode fields (see Figure V-4) in this Unity shall be set to all zeros, except for the ZERO field, which shall count from 0 to 9 to label the successive frames in the Unity, and S0,S1 and the CRC field, which shall be encoded according to the normal rules (see chapter V.4.3).

User Data byte	Contents
0..4	RID code identifier “RID01”
5..7	Reserved and set to 00h
8 9 10	RID Manufacturer Code (I_1) ‘A’..Z’ RID Manufacturer Code (I_2) ‘A’..’Z’ RID Manufacturer Code (I_3) ‘A’..’Z’
11..15	Reserved and set to 00h
16 17 18 19	RID Recorder Type Code (I_4) ‘A’..’Z’ RID Recorder Type Code (I_5) ‘A’..’Z’ RID Recorder Type Code (I_6) ‘0’..’9’ RID Recorder Type Code (I_7) ‘0’..’9’
20..23	Reserved and set to 00h
24 25 26	RID Recorder Unique Number (0, I_8) RID Recorder Unique Number (I_9, I_{10}) RID Recorder Unique Number (I_{11}, I_{12})
27..31	Reserved and set to 00h
32..63	Manufacturer name
64..79	Supplementary Recorder Type Code
80..95	Supplementary Recorder Unique Number
96..127	Reserved and set to 00h
128..255	Reserved and set to 00h
256..1023	Manufacturer specific
1024..2047	Reserved for copy protection purposes

byte 0..127 = Recorder identification: see chapter V.2.3.1
byte 128..255 = Reserved and set to 00h
byte 256.. 1023 = Manufacturer specific: see chapter V.2.3.1
byte 1024..2047 = Reserved for copy protection purposes (if not used set to 00h)

Figure V-5 Definition of the User Data bytes in the PMA main channel blocks

V.5 Lead-in Area

The Lead-in Area contains information about the disc (or the Session to which it belongs) and about the recorded Tracks.
A Lead-in Area can be in one of the following states:

- unrecorded;
- recorded and finalized, the TOC must be in accordance with the contents of the PMA (only Copy bit is allowed to be different, see chapter V.4.3);

In the Lead-in, information is encoded in the Subcode Q-channel. The Subcode-Q modes are used according to the Red Book.
In a finalized Lead-in Area the following Subcode modes are present:
Mode 1 is always present. The format of mode 1 is according to the Red Book, and contains the start positions of the recorded Tracks. See chapter V.5.2 mode 1.
Mode 5 is optional, unless the disc is a Multisession disc (see chapter XI).
Within mode 5 the identification of the Multisession CD-R disc is defined, see chapter V.5.2 mode 5. Optionally, mode 5 can contain information about recorded Tracks or parts (Time Intervals) of recorded Tracks that should be skipped during play back of the disc.
Mode 6 is always and only present in the first Lead-in Area. Mode 6 shall contain a copy of the “Disc Identification” Item as recorded in the PMA (ADR = 2), see chapter V.5.2 mode 6.

If both mode 1 and mode 5 are present, they must be placed in alternating order, each Subcode block being repeated three times. When used, mode 1 and mode 5 each occupy at least 3 out of 10 successive Subcode blocks.
Mode 6 shall occupy at least 1 out of 100 successive Subcode blocks.

V.5.1 ATIP/Subcode synchronization

In the Lead-in Area the time value encoded in MIN, SEC, FRAME of Subcode channel-Q is identical to the ATIP time-code.
The end of the Lead-in Area is encoded with a time-code of 99 Minutes, 59 Seconds, 74 Frames in both ATIP and Subcode-Q.

V.5.2 Table of Contents

When a Session on a CD-R disc is finalized, the Lead-in Area with the Table of Contents is written. After finalization, the TOC must contain the actual status of the complete contents of that Session. Additional recordings are possible in a new Session, when the disc has been finalized as a Multisession disc with mode 5 in the subcode of the Lead-in Area (see chapter XI). If the complete disc has to be readable on a CD-ROM (or CD-DA) drive, then all Sessions must be finalized.

The Lead-in Area with the Table of Contents of the first (or only) Session starts at the start-time as indicated in ATIP (see chapter IV.4.2). This Lead-in area ends at Absolute Time 99:59:74, this corresponds to diameter 50 +0.0/-0.4 mm.
In the TOC the Items are repeated three times each. The complete TOC is continuously repeated during the Lead-in Area. If mode 1 and mode 5 are both present, each mode must be repeated separately (see Figure XII-15 and Figure XII-16).

Figure V-6   Encoding in the Lead-in Area of a Subcode-Q frame

S0,S1	CONTROL	ADR	00	POINT	MIN	SEC	FRAME	ZERO	PMIN	PSEC	PFRAME	CRC
			TNO									

S0, S1 : According to the Red Book page 40.

CONTROL : See CONTROL in chapter V.6.3.1, except for bit 1 (the Copy Bit). If ADR=1 (TOC Item) then the Copy Bit is '1' (no copyright) only if the Copy Bit is '1' in all parts of the Track specified by POINT.
Note: The correct copyright status of a Track must always be checked in the Program Area.

TNO : 00

CRC : see Red Book page 41: 16 bit CRC on Control, ADR and Q-data (MSB first). On the disc the parity bits are inverted. The remainder have to be checked at zero. The check polynomial is: $P(X) = X^{16} + X^{12} + X^{5} + 1$

ADR = 1 : Mode 1

MIN, SEC, FRAME :
indicate Absolute Time on the disc. They must be identical to the ATIP-time.

ZERO = 00

POINT = 01 .. 99 :
The value of PMIN, PSEC and PFRAME gives the start position of the recorded Track pointed to by POINT.

POINT = A0 :
a) PMIN gives the value of the first recorded Track number in the Program Area.
b) PFRAME is 00.
c) PSEC specifies the Session format.
The allowed values (in hex) are:
00 : CD-DA and CD-ROM
10 : CD-i
20 : CD-ROM-XA

POINT = A1 :
a) PMIN gives the value of the last recorded Track number in the Program Area.
b) PSEC and PFRAME are 00.

POINT = A2 :
PMIN, PSEC and PFRAME gives the start position of the Lead-out Area.

ADR = 5 : Mode 5

Multisession pointers (see Figure XII-16):

POINT=B0
This pointer, together with POINT=C0, is used to indicate a Multisession disc. POINT=B0 is present in the Lead-in Area of each Session of a Multisession disc. If the disc is not a Multisession disc, then POINT=B0 is not present.

a) MIN, SEC, FRAME give the start time of the next possible Program Area in the Recordable Area of a Multisession CD-R disc.
   If the last Session on a Multisession disc is designated as the Final Session of that disc, then MIN, SEC, FRAME shall contain the values 'FF, FF, FF' (hex). Alternatively, POINT=B0 can be omitted in the Lead-in Area of the Final Session of a disc.
b) PMIN, PSEC, PFRAME give the start time of the Additional Capacity & Lead-out Area in the Recordable Area of a CD-R disc (copied from ATIP).
c) ZERO gives the total number of different pointers present in mode 5 (including any Audio Skip pointers).

POINT=C0
This pointer, together with POINT=B0, is used to indicate a Multisession disc. POINT=C0 is only present in the first Lead-in Area of a Multisession disc. If the disc is not a Multisession disc, then POINT=C0 is not present.
MIN, SEC and FRAME contain a copy of the corresponding ATIP fields, encoded during the Lead-in Area (see chapter IV.4), in the specially encoded ATIP frames with MSB combination 101 (Special Information 1, see chapter IV.4.1):

a) MIN : This value must be copied from the value, encoded in the ATIP "Minutes" byte of the ATIP frames with MSB combination 101.
   Bit 7..1 : W1..W3, X1, V1..V3 (bit 7 = MSB)
   Bit 0 = 0
b) SEC : This value must be copied from the value, encoded in the ATIP "Seconds" byte of the ATIP frames with MSB combination 101.
   Bit 7..1 : U1..U7 (bit 7 = MSB)
   Bit 0 = 0
c) FRAME : It is recommended that this value is a copy from the value, encoded in the ATIP “Frames” byte of the ATIP frames with MSB combination 101.
   Bit 7..1 : D1, B1..B3, A1..A3 (bit 7 = MSB)
   Bit 0 = 0
   If this value is not a copy from the specified ATIP value, then all bits 7..0 shall be set to 0.
d) ZERO : Reserved and set to zero.
e) PMIN, PSEC, PFRAME :
   give the start time of the first Lead-in Area of the disc.

POINT=C1,C2,C3
These pointers are reserved for future extensions and shall not be used (see chapter I.3).

ADR = 5 : Mode 5

Audio Skip pointers (see Figure XII-15):

POINT=B1
This pointer is used to indicate that an Audio Session contains Intervals and/or Tracks that should be skipped during playback (not allowed in Data Sessions).
a) MIN, SEC, FRAME, ZERO, PFRAME = 00
b) PMIN gives the number N (N≤40) of Skip Interval Pointers POINT=01..N.
c) PSEC gives the number M (M≤21) of Skip Track assignments in POINT=B2..B4.
If no Skip Interval Pointers and no Skip Track assignments are used, POINT=B1 is not present.

POINT=B2..B4
Each of these pointers indicate maximally seven Track numbers that should be skipped during playback. The number M of used Skip Track assignments is given in PSEC of POINT=B1. If no Skip Track assignments are used (M=0), POINT=B2..B4 are not present.
a) MIN, SEC, FRAME, ZERO, PMIN, PSEC, PFRAME each give a value of a Track number that should be skipped during play back. Remaining, unused bytes within a block must be filled with 00.

POINT=01..40
These are the Skip Interval Pointers. They indicate an Interval (time interval) on the recorded disc that should be skipped during play back. Intervals must be recorded chronologically. The number N of used Skip Interval Pointers is given in PMIN of POINT=B1. If no Skip Interval Pointers are used (N=0), POINT=01..40 are not present.
a) The value of PMIN, PSEC, PFRAME gives the start time of an Interval on the disc that should be skipped during play back.
b) The value of MIN, SEC, FRAME gives the stop time of the Interval indicated in a).
c) ZERO = 00: Reserved

Remark: Different Skip Intervals must not overlap each other, and Skip Intervals must not overlap with Skip Track assignments.

ADR = 6 : Mode 6

Disc Identification

POINT = 00
This pointer is used to identify the disc by a statistically unique 24-bit binary number. Mode 6, POINT=00 is only present in the first Lead-in Area (also on a Single Session disc).

MIN, SEC, FRAME :
indicate Absolute Time on the disc. They must be identical to the ATIP-time.

ZERO = 00

PMIN, PSEC and PFRAME shall contain a copy of the Disc Identification Item as recorded in the PMA with ADR = 2 (see chapter V.4.3).
PMIN shall be equal to the MIN field of the Subcode blocks with ADR = 2 in the PMA.
PSEC shall be equal to the SEC field of the Subcode blocks with ADR = 2 in the PMA.
PFRAME shall be equal to the FRAME field of the Subcode blocks with ADR = 2 in the PMA.

POINT = 01..99 :
Reserved for future extensions.

V.5.3 Subcode/Header synchronization

If the Lead-in Area is encoded as a Data Track (see Yellow Book chapter VI.3) then the Header address and the Subcode-Q Relative Time before CIRC/EFM encoding with a minimum delay encoder (see Yellow Book page 33) must be identical.

V.6 Program Area

The Program Area consists of Tracks which are recorded, reserved or incomplete.
The Program Area can be recorded partially, in which case there can be unrecorded areas. Unrecorded areas are only allowed at the end of Reserved Tracks and at the end of the last Program Area (see chapters V.4.1.1 and V.4.1.2).
Recordings can be made by writing in an unrecorded area of the disc. Writing in an unrecorded area has to start at the beginning of a Reserved Track or has to be linked directly to the end of the last recording before the unrecorded area.

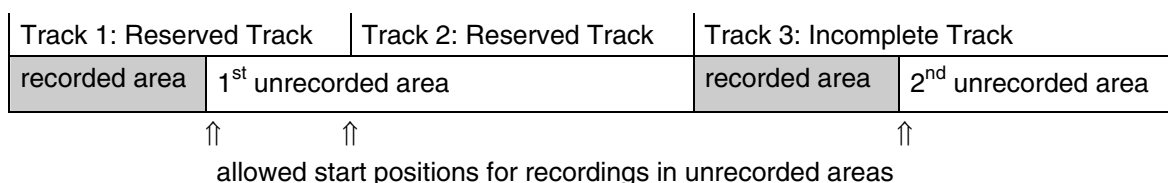



Figure V-7 Example of start positions for recordings in unrecorded areas

Any recording must fulfill all the linking rules (see chapter V.2) and has to be according to the Track attributes as described in the Track Descriptor Block for data tracks (see chapter V.6.5.2).

V.6.1 ATIP/Subcode synchronization

In the Program Area the Subcode-Q Absolute Time is identical to the ATIP time code.
The first ATIP and Subcode-Q time code in the Program Area is zero (0 Minutes, 0 Seconds, 0 Frames).

V.6.2 Subcode/Header synchronization

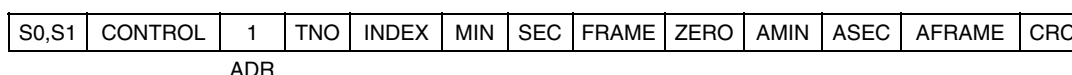
The Header address and the Subcode-Q Absolute Time before CIRC/EFM encoding with a minimum delay encoder (see Yellow Book page 33) are identical.

V.6.3 Subcode Q-Channel

V.6.3.1 Subcode Q-Channel mode 1

The Q-channel data in the Program Area are according to the Red Book except when specified otherwise in this chapter.

Figure V-8 Encoding in the Program Area of a Subcode-Q mode 1 frame

S0,S1	CONTROL	1	TNO	INDEX	MIN	SEC	FRAME	ZERO	AMIN	ASEC	AFRAME	CRC
		ADR										

CONTROL	:	Identification of the kind of information within a Track (bit 3 is first bit and MSB).
bit 3..0	:	The Encoding Identification. The only allowed change of the Encoding Identification within a Track is between "audio without pre-emphasis" and "audio with pre-emphasis".
= 00x0	:	2 audio channels without pre-emphasis
= 00x1	:	2 audio channels with pre-emphasis
= 01x0	:	Data Track, recorded uninterrupted.
= 01x1	:	Data Track, recorded incremental.
= 10x0	:	Reserved
= 10x1	:	Reserved
= 11x0	:	Reserved
= 11x1	:	Reserved
bit 1	:	The three states of this Copy Bit are: continuous 1, continuous 0, or alternating 1 and 0. It is allowed to change the state of the Copy Bit during a Track. The use of the Copy Bit states is defined in attachment XIII.12.
= continuous 0	:	Track is copy-right protected.
= continuous 1	:	Track is not copy-right protected, and copying is permitted.
= alternate 1/0	:	Track is first or higher generation copy of a copy-right protected Track. The frequency for alternating between 1 and 0 is 9.375 Hz (duty-cycle 50%), which means successively four Subcode frames 1 and four frames 0.
ADR = 1	:	Mode 1
TNO, INDEX	:	Track- and Index-number
MIN, SEC, FRAME	:	Relative Time within a Track.
ZERO = 00	:	Reserved
AMIN, ASEC, AFRAME	:	Absolute Time in-line with ATIP of unrecorded disc
CRC	:	see Red Book page 41: 16 bit CRC on Control, ADR and Q-data (MSB first). On the disc the parity bits are inverted. The remainder have to be checked at zero. The check polynomial is: $P(X) = X^{16} + X^{12} + X^5 + 1$

V.6.3.2 Subcode Q-Channel mode 3

Consumer CD-recorders shall write mode 3 of the Subcode Q-channel to record the following codes:
- the ISRC (International Standard Recording Code) according to the Red Book,
- the RID code (Recorder IDentification code) according to this specification, and
- a TBD code, the contents of which are reserved for future use.

These codes are encoded in 60 bits of the Subcode frame, grouped into 12 bit groups according to Figure V-9:

I_1 .. I_5, each consisting of 6 bits, occupying bit positions 0 .. 29
I_6 .. I_{12}, each consisting of 4 bits, occupying bit positions 32 .. 59

The identification of the 3 different codes is achieved by C1,C2 on bit positions 30 and 31, between I_5 and I_6.

Figure V-9 Encoding in the Program Area of a Subcode-Q mode 3 frame

S0,S1	CONTROL	3	I_1 I_2 I_3 I_4 I_5	C_1 C_2	I_6 I_7 I_8 I_9 I_{10} I_{11} I_{12}	ZERO	AFRAME	CRC
		ADR	6 bits each	2 bits	4 bits each			

C_1C_2 = 00 : I_1 .. I_{12} = ISRC code : according to Red Book, section 4.3
= 11 : I_1 .. I_{12} = RID code : see below
= 01 : I_1 .. I_{12} = TBD code : Reserved, all bits set to 0
= 10 : not used

ZERO: 4 bits = 0000

AFRAME: 8 bits = the frame value of the Absolute Time, in-line with ATIP of unrecorded disc

V.6.3.2.1 Data format of the RID code

I_1 .. I_5 are representing alphanumeric characters, coded in a 6-bits format according to the Red Book, section 4.3.
I_6 and I_7 are coded as two 4-bits BCD numbers.
I_8 .. I_{12} are coded as one 20-bits unsigned binary number with MSB first.

The RID code is composed of 3 groups in the following way:
group 1: I_1, I_2 and I_3 represent the Manufacturer Code (example: "PHI")
group 2: I_4, I_5 and I_6, I_7 represent the Type Code (example: "CR 27")
group 3: I_8 .. I_{12} represent a Recorder Unique Number (example: "87532")
Example of complete RID code: "PHI CR 27 87532"

Note: The Manufacturer Code shall be issued and registered by Royal Philips Electronics (for detailed address see "Conditions of publication" in this document). The Type Code and the Recorder Unique Number (unique for each single recorder unit) are defined by the recorder manufacturer.

V.6.3.2.2 General format of mode 3

In the Program Area mode 3 shall occupy 1 out of 100 ± 5 successive Subcode frames. All 3 codes shall be written in the following repeated sequence from the start of the Track (Index 1): 2 ISRC entries, 1 RID entry, 2 ISRC entries, 1 TBD entry, and so on. If the ISRC is not used, then all bits in I_1 .. I_{12} of the ISRC must be set to 0. If the TBD code is not used, then the RID code is used instead of the TBD code, or all bits in I_1 .. I_{12} of the TBD code must be set to 0. In CD-R, multiple ISRC codes within one Track are allowed.

V.6.4 P, R..W Subcode channels

The P-bit = 1 for the first two seconds in the Program Area. For the remainder of the disc, the P-bit must be either set to zero or be used as specified in the Red Book.
The channels R..W are according to the Red Book. If they are not used they must be zero.

V.6.5 Data Tracks

Every Data Track must start with a Pre Gap. It is recommended that every uninterrupted written data Track is ended with a Post Gap of minimum 2 seconds.

V.6.5.1 The Pre Gap

The use of the Pre Gap is clarified in attachment XIII.10.

- When the use of a Pre Gap is prescribed in the Yellow Book or the Green Book, the definitions according to these books must be used. The second part of this Pre Gap contains the Track Descriptor Block (see chapter V.6.5.2).
- When no Pre Gap is prescribed according to the Yellow Book or the Green Book, a Pre Gap of 2 seconds (150 blocks) must be recorded. This Pre Gap contains the Track Descriptor Block.

The Pre Gap is characterized by:

a: In the Subcode Q-Channel:
  - ∗ INDEX = 00
  - ∗ Relative time (MIN, SEC, FRAME) decreases to 00:00:00 at the end of the Pre Gap.

b: In the main channel:
  - ∗ The data is block encoded according to one of the Mode numbers as specified in the Yellow Book or the Green Book.

If a Track is written incrementally, then the (second part of the) Pre Gap must be composed of one Packet, in such away, that after writing the first User Data packet in the Track, the Pre Gap ends with the fourth Run-in block. The header address of the first User Data Block in the Track must be the start time of the Track, see Figure V-10.

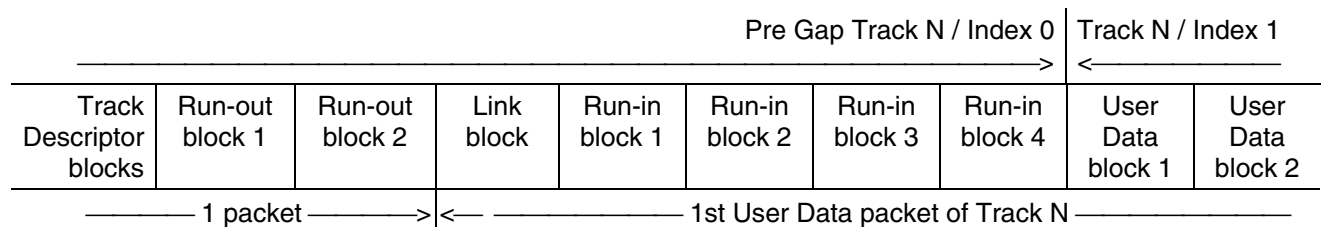



Figure V-10 Linking of the first User Data in the Track to the Pre Gap

If a Track is not written incrementally, then the (second part of the) Pre Gap and all User Data Blocks in the Track must be recorded in one Packet; this is called Track At Once (TAO) recording.

V.6.5.2 The Track Descriptor Block

(see Figure XII-17)
The Track Descriptor Block is mandatory for Incremental written Data Tracks (packet writing), for Track At Once (TAO) recording and for Data Tracks written in a Session At Once (SAO) recorded Session. For Tracks written during Disc At Once (DAO), it is recommended not to write the Track Descriptor Blocks.

The Track Descriptor Block contains in the User Data Field information about the Track attributes of the current Track. Optionally it contains the track attributes of all preceding tracks.
The User Data Field within a Track Descriptor Block consists of two parts:
a: Track Descriptor Table. This table is at the beginning of each User Data Field and is eight bytes long (see chapter V.6.5.2.1).
b: One or more Track Descriptor Units. A unit consists of sixteen bytes. The first Track Descriptor Unit is placed directly after the Track Descriptor Table (see chapter V.6.5.2.2).
Not used bytes between the end of the last Track Descriptor Unit and the end of the User Data field of a Track Descriptor Block are filled with zeros.

V.6.5.2.1 The Track Descriptor Table

The contents of these eight bytes in the main channel are (see Figure XII-17):

Byte 0..2 : **T**rack **D**escriptor **I**dentification.
These three bytes contain the Hexadecimal code: '54 44 49' (ASCII "TDI").
Byte 3..4 : Pre Gap length.
The number of blocks of the second part of this Pre Gap, encoded in BCD.
Byte 5 : Indicates which Track Descriptor Units are present.
= 00 : Indicates that Track Descriptor Units of previous tracks are present in this Track Descriptor Block.
= 01 : Indicates that only the Track Descriptor Unit of the current Track is present in this Track Descriptor Block.
= others : Reserved.
Byte 6 : The lowest Track number described in this Track Descriptor Block, encoded in BCD.
Byte 7 : The highest Track number described in this Track Descriptor Block, encoded in BCD.

V.6.5.2.2 The Track Descriptor Unit

A Track Descriptor Unit consists of 16 bytes in the main channel. They describe the Data attributes of a Track. The contents of these 16 bytes are (see Figure XII-17):

Byte 0 : Number of the Track to which this Track Descriptor Unit belongs, BCD encoded.

Byte 1 : Write method of the Track (bit 7 = MSB).
Bit 7..4 = 1000 : Uninterrupted written Data Track.
The Track consists of only one Packet.
Bit 3..0 : Reserved and set to zero.

= 1001 : Incremental written Data Track.
The Track consists of more than one Packet.
Bit 3..0 = 0000 : variable Packet Size.
= 0001 : fixed Packet Size.
= other : Reserved.

= 0000 : Uninterrupted written Audio Track.
Bit 3..0 : Reserved and set to zero.

= other : Reserved.
Bit 3..0 = Reserved.

Byte 2..4 : Packet Size.

a: For Incremental written Tracks with fixed Packet Size (Byte 1='91' hex), these bytes contain the BCD encoded Packet Size in blocks (MSByte first).

b: For Incremental written Tracks with variable Packet Size (Byte 1='90' hex), and Uninterrupted written Data Tracks (Byte 1='80' hex), these three bytes contain the code 'FF FF FF' (hex).

Byte 5..15 : Reserved and set to zero.

V.6.6 ATIP/Header synchronization

The start of a Block-Sync (before encoding with a minimum delay encoder, see Yellow Book page 33) is within -10 and +36 EFM frames after the (detected) ATIP Sync (see Figure XII-10).

V.7 Lead-out Area

V.7.1 Lead-out Area

If the disc is a single Session disc, then the recorded EFM in the Lead-out Area is encoded according to the rules given in the Red Book. The Lead-out Area is at least 1.0 mm in diameter wide, with a minimum recording time of 1 minute and 30 seconds.

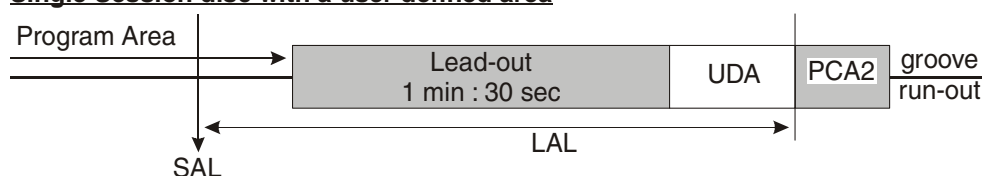
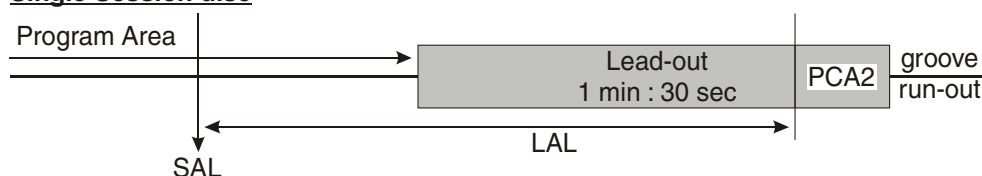
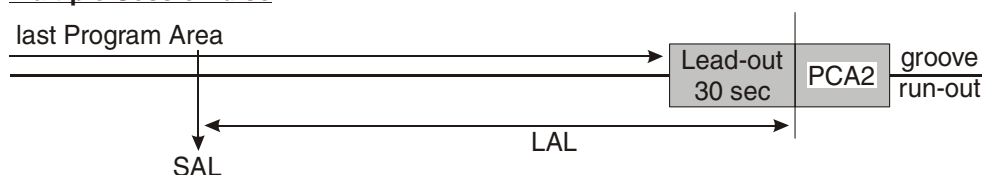
If the disc is a Multisession disc, then the recorded EFM in each Lead-out Area is encoded according to the rules given in the Multisession Compact Disc specification. The Lead-out Area of the first Session has a length of 1 minute and 30 seconds; the Lead-out Area of a second or higher Session has a length of 30 seconds.

The last possible start time of a Lead-out is determined by:

- Length of the last Lead-out
- Length of an optional user defined area (UDA)

If the disc capacity is not fully used, there can be a blank area between the Lead-out and PCA2.

Examples:

Single Session disc with a user defined area

Single Session disc

Multiple Session disc

Warning:
Drives not compliant with this version of this document, might not be able to finalize discs with a Program Area exceeding the start time of Additional Capacity & Lead-out Area.

V.7.1.1 ATIP/Subcode synchronization

In the Lead-out Area the Subcode-Q Absolute Time is identical to the ATIP time code .

VI. EFM Modulation system

See Red Book pages 13 up to and including 26.

VII. CIRC Error correction system

Audio tracks : See Red Book pages 27 up to and including 38.
Data tracks : See Yellow Book pages 27 up to and including 38.

VIII. Control and display system

Audio tracks : See Red Book "CONTROL AND DISPLAY SYSTEM".
Data tracks : See Yellow Book "CONTROL AND DISPLAY SYSTEM".

IX. Audio specification

See Red Book pages 1 and 1a.

X. Digital data structure

See Yellow Book pages 1, 1a and 100 up to and including 112.

XI. Multisession and Hybrid disc

XI.1 Introduction and Definitions

An area on the disc consisting of a Lead-in Area, a Program Area and a Lead-out Area is called a **Session**.
If a disc contains or can contain more than one Session then this disc is called a **Multisession disc**.
A **Hybrid disc** is a Multisession disc of which the first Session is a Mastered Session.

A Session is finalized if the Program Area is fully recorded and the Lead-in and Lead-out Areas of the Session are recorded.
If a disc leaves the recorder then all Sessions except the last one must be finalized.
The last recorded Session on a disc can be designated as the "Final Session" (see chapter V.5.2), in this case the recording of additional Sessions is prohibited.

A Multisession CD-R disc shall be recorded according to the rules for CD-R (CD-WO) in the "Multisession Compact Disc" specification, unless specified otherwise in this document.

XI.2 PCA1, PCA2 and PMA

PCA1, PCA2 and the PMA of a Multisession disc are according to the definitions in the chapters V.3 and V.4 of this document.
If a disc leaves the recorder then the PMA must contain the actual status of the data of all Tracks of all Sessions on that disc.

XI.3 Lead-in Areas

See "Multisession Compact Disc Specification" chapter III.2.

XI.4 Program Areas

See "Multisession Compact Disc Specification" chapter III.3.

XI.5 Lead-out Areas

See "Multisession Compact Disc Specification" chapter III.4.

XI.6 Data Retrieval Structure

See "Multisession Compact Disc Specification" chapter IV.

XI.7 Hybrid disc: disc characteristics

The recordable parts of a hybrid disc must fulfill the specifications described in chapter II.4: the unrecorded disc.
The recorded as well as the mastered parts of a hybrid disc must fulfill the specifications described in chapter 0: The Recorded Disc.
However: the specifications concerning max. variation of R_{top} (±3%) and max. variation of push-pull (±15%, see Red Book page 7) are allowed to be fulfilled for the recorded and the mastered parts <u>separately</u>.

XII. Figures and Tables

Figure XII-1 Layout of the Unrecorded disc

Figure XII-2 Example of the layout of a Partially Recorded disc with one Session

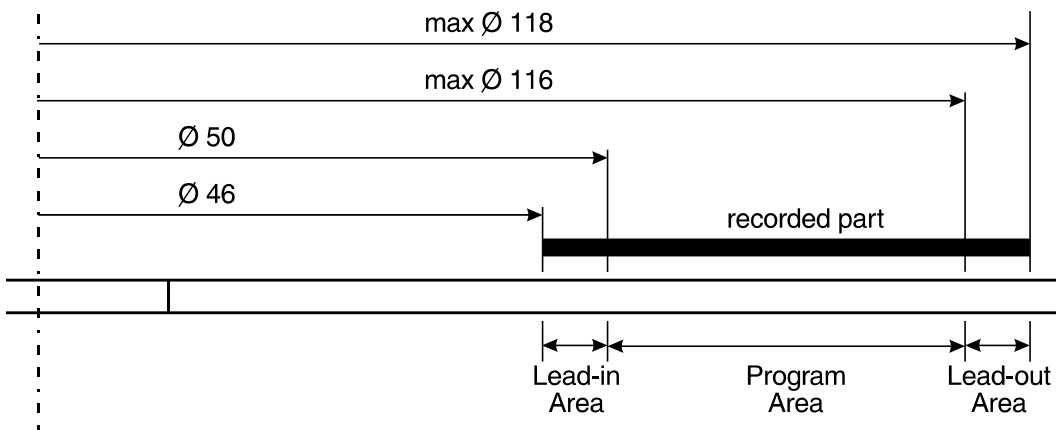



Figure XII-3 Example of the layout of a Finalized disc with one Session

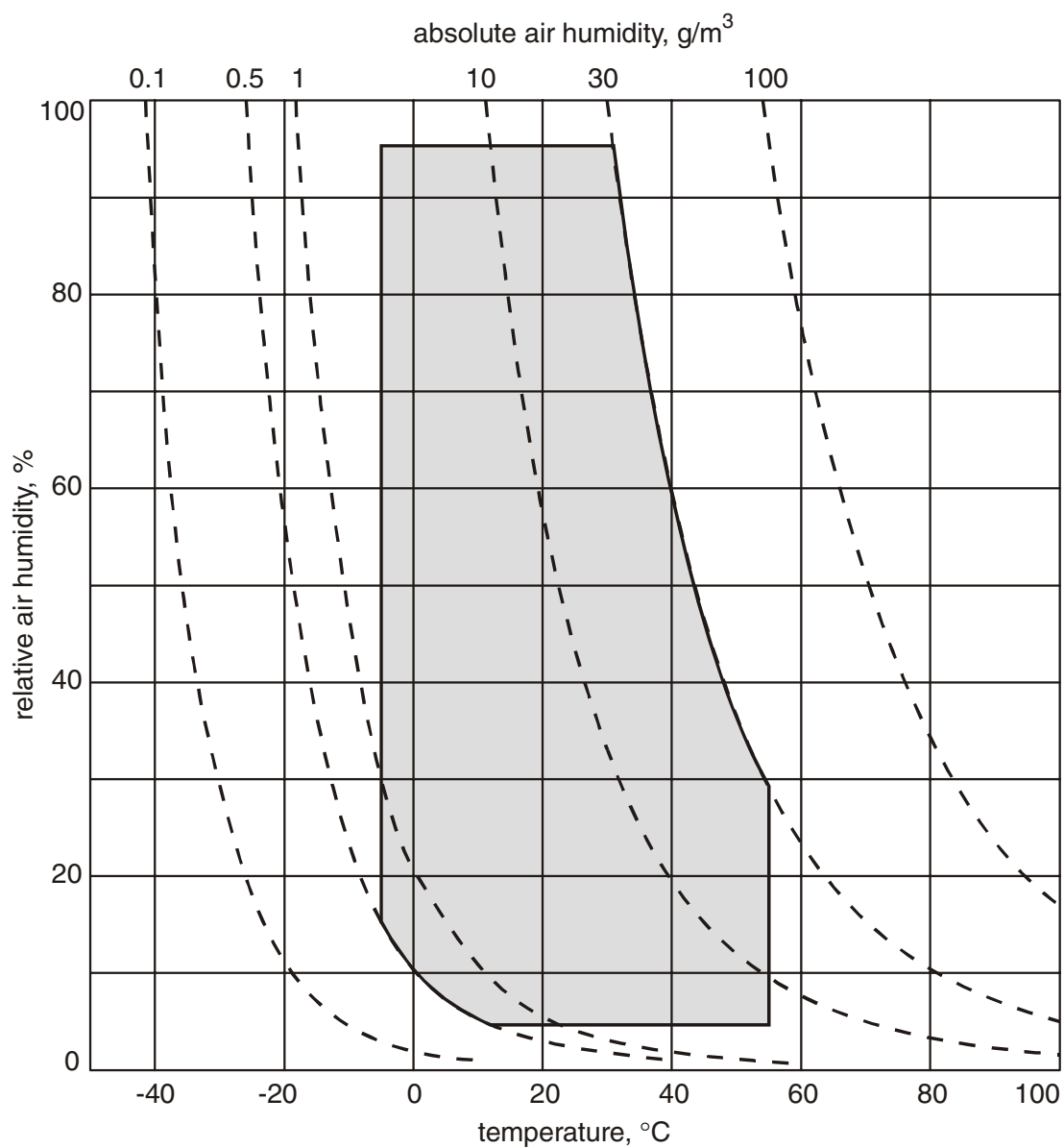



Figure XII-4 Operating conditions

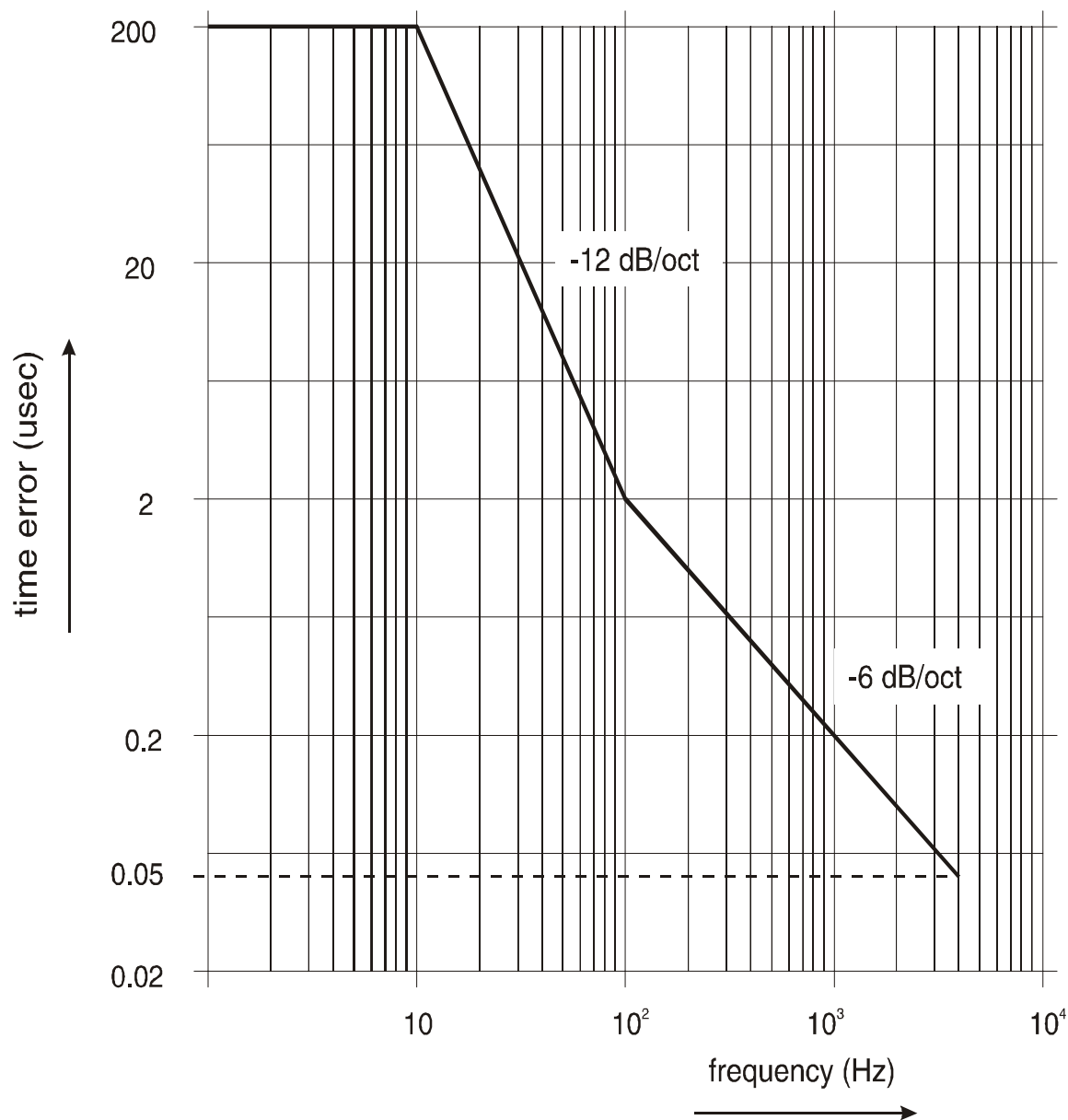



Figure XII-5   Maximum allowed time errors versus frequency spectrum

t_0	=	Start time XAA (= start time XIA)	= t_3 - 01:00:00
t_x	=	Start time XAA buffer	= t_3 - 00:37:00
t_1	=	Start time PCA1	= t_3 - 00:35:65
t_2	=	Start time PMA	= t_3 - 00:13:25
t_3	=	Start time Lead-in Area	= encoded in ATIP
t_4	=	End time Lead-in Area Start time Program Area	= 99:59:74 = 00:00:00
t_5	=	start time Additional Capacity & Lead-out Area	= SAL encoded in ATIP
t_6	=	Start time PCA2	= t_5 + LAL encoded in ATIP
t_7	=	End time PCA2 Area	= t_6 + 00:22:40

Figure XII-6 ATIP versus disc diameters

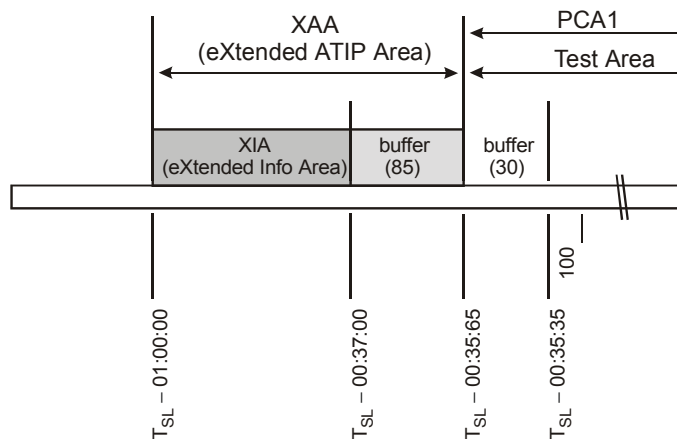



Figure XII-7 Details of Extended ATIP Area (XAA)

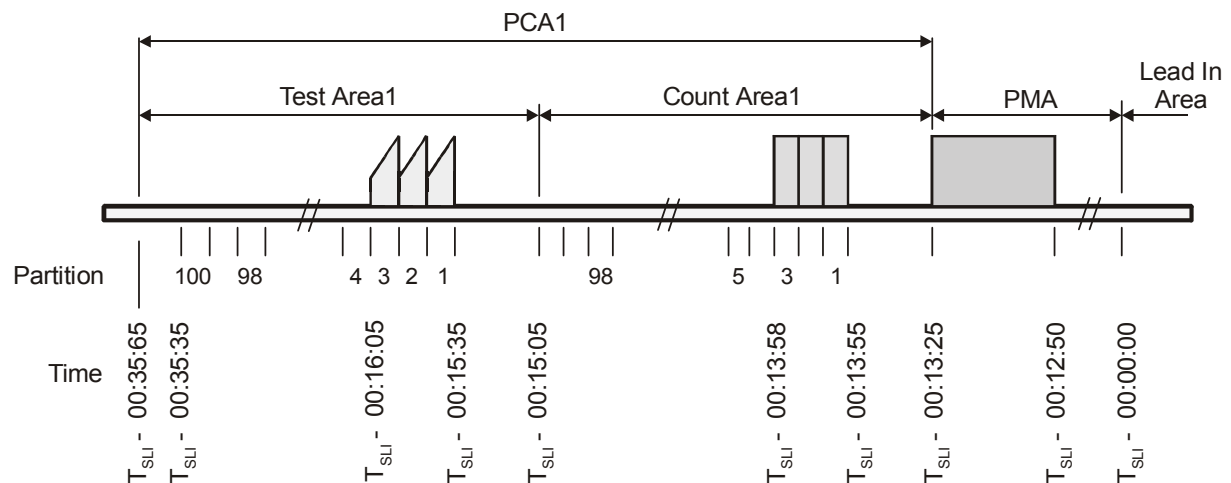



Figure XII-8 Organization of the PCA1, PMA and Lead-in Area

- * The disc is an incremental, partially recorded CD-R disc.
- * T_{SLI} = start time of the Lead-in Area, as encoded in ATIP.
- * The hatched area's are recorded parts of the disc.

In the **Program Area** of this disc there are:

- Track 1,2 and 3 (recorded uninterrupted, e.g. recorded on recorder A).
- Track 4 (e.g. recorded on recorder B).
- Track 5 and 6 (recorded uninterrupted, e.g. recorded on recorder C).

In the **Power Calibration Area (PCA1)** of this disc there are:

- In the Test Area1: recorded data according to Optimum Power Control (OPC) procedure in partition 1 up to and including 3.
- In the Count Area1: recorded EFM data in partition 1 up to and including 3.

In the **Program Memory Area (PMA)** of this disc there are:

- 50 ATIP frames recorded: Disc Identification (first 10 frames) and track data of Track 1 to 6 (last 40 frames).

In the **Lead-in Area** of this disc there are:

- no data recorded, because disc is not yet finalized (see chapter V.5.2).

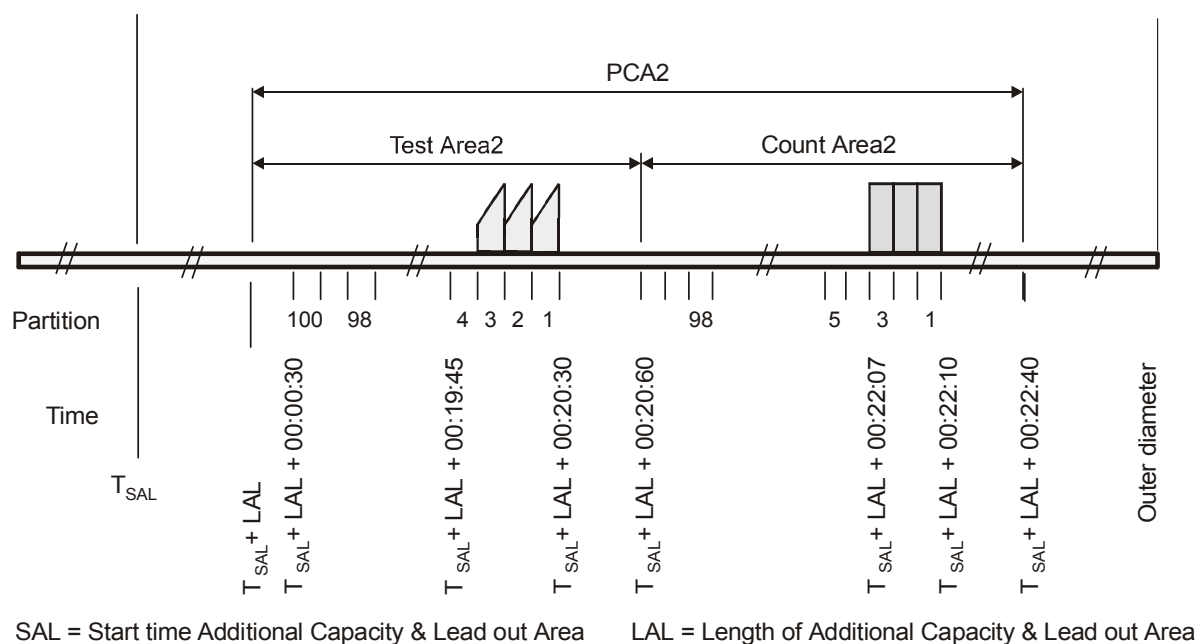



Figure XII-9 Organization of the PCA2 area in the Additional Capacity & Lead out Area

* T_{SAL} = start time of the Additional Capacity & Lead-out Area, as encoded in ATIP.

* The hatched area's are recorded parts of the disc.

In the **Power Calibration Area 2 (PCA2)** of this disc there are:

- In the Test Area2: recorded data according to Optimum Power Control (OPC) procedure in partition 1 up to and including 3.
- In the Count Area2: recorded EFM data in partition 1 up to and including 3.

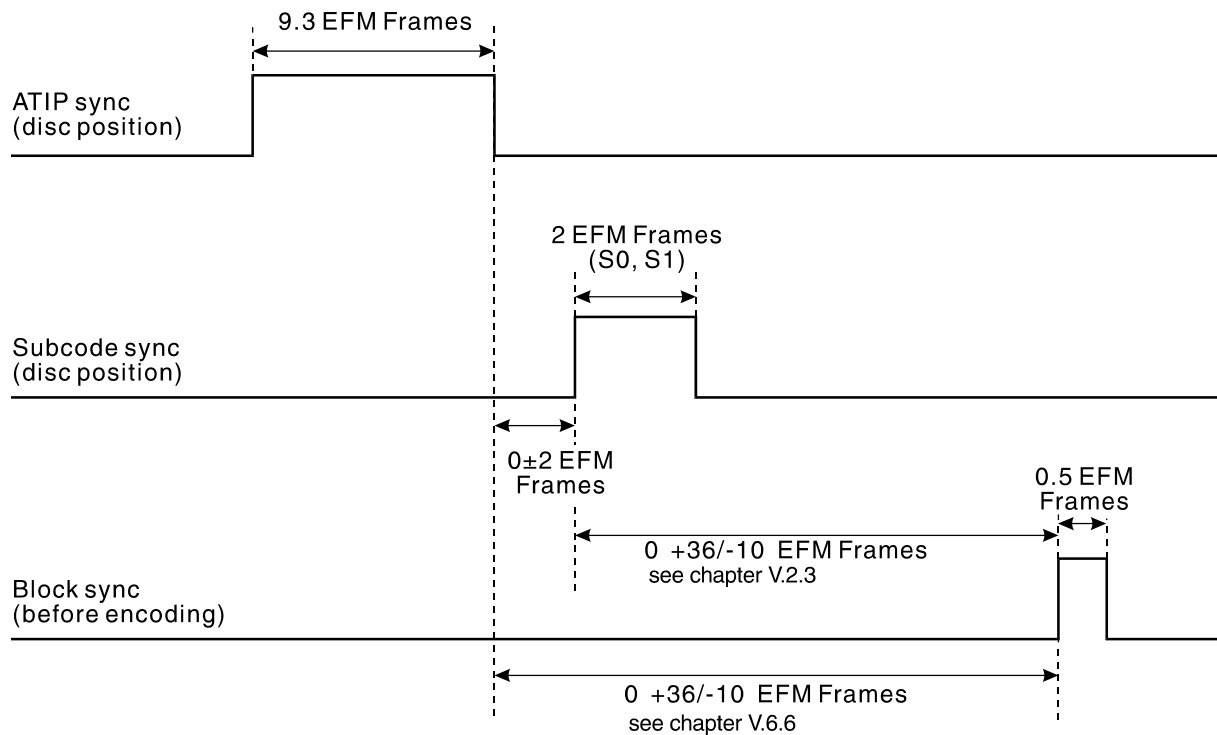



Figure XII-10 Synchronization rules

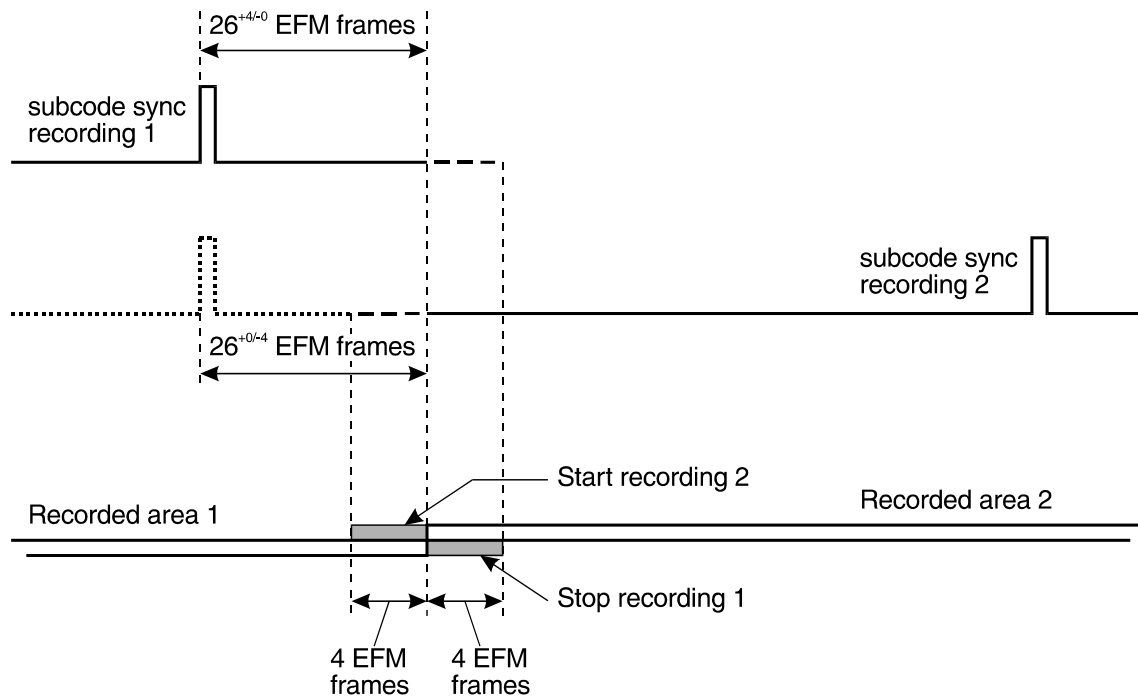



Figure XII-11 General linking rules

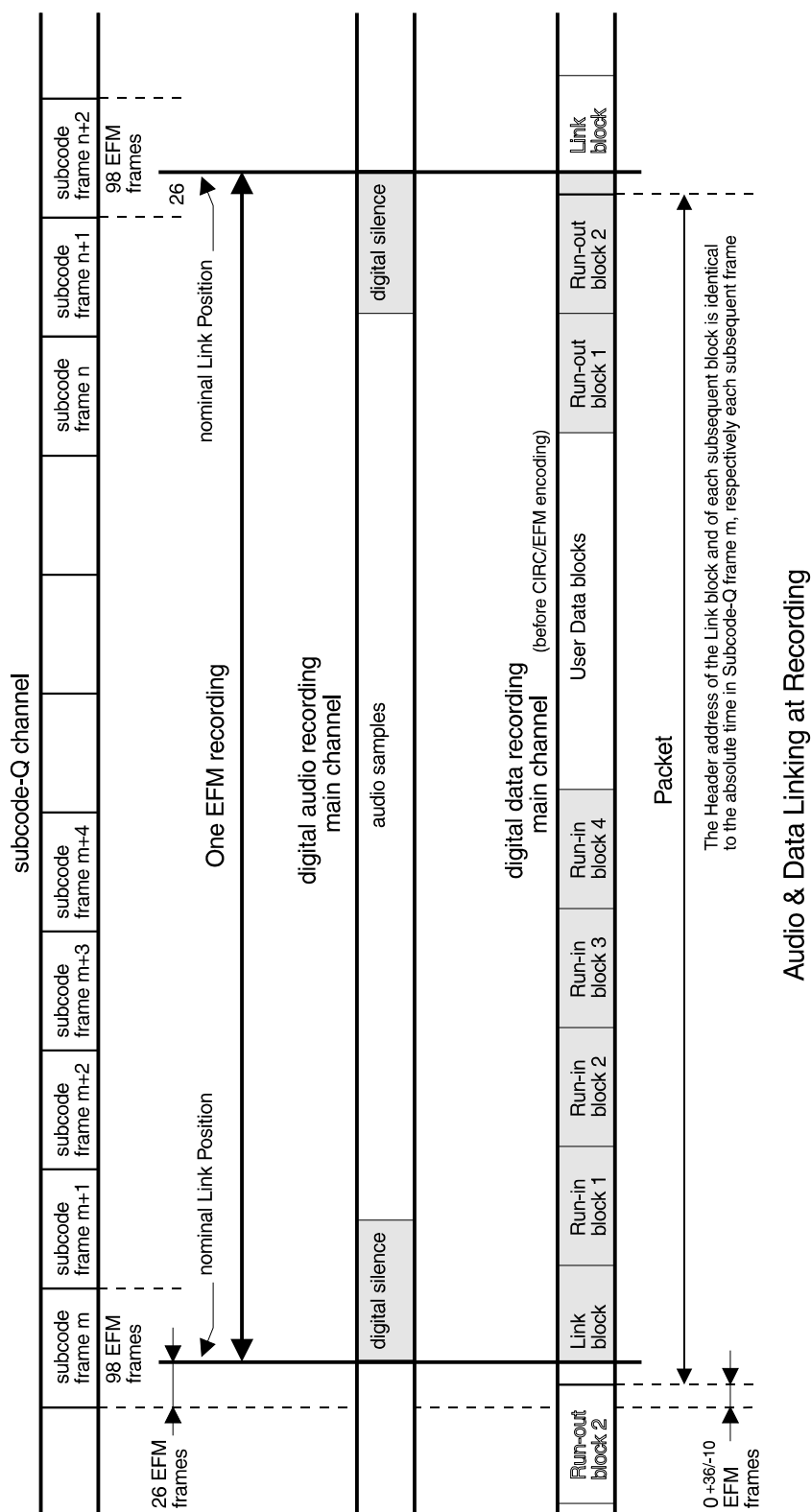
Figure XII-12 Linking rules for audio & data

Frame Number	CONTROL & ADR	TNO	POINT	MIN	SEC	FRM	ZERO	PMIN	PSEC	PFRM
1	02	00	00	20	15	14	00	00	00	00
2	02	00	00	20	15	14	01	00	00	00
3	02	00	00	20	15	14	02	00	00	00
4	02	00	00	20	15	14	03	00	00	00
5	02	00	00	20	15	14	04	00	00	00
6	02	00	00	20	15	14	05	00	00	00
7	02	00	00	20	15	14	06	00	00	00
8	02	00	00	20	15	14	07	00	00	00
9	02	00	00	20	15	14	08	00	00	00
10	02	00	00	20	15	14	09	00	00	00
11	01	00	01	05	45	67	00	00	02	01
12	01	00	01	05	45	67	01	00	02	01
13	01	00	01	05	45	67	02	00	02	01
14	01	00	01	05	45	67	03	00	02	01
15	01	00	01	05	45	67	04	00	02	01
16	01	00	02	12	01	09	05	05	45	67
17	01	00	02	12	01	09	06	05	45	67
18	01	00	02	12	01	09	07	05	45	67
19	01	00	02	12	01	09	08	05	45	67
20	01	00	02	12	01	09	09	05	45	67
21	01	00	03	30	17	42	00	12	04	09
22	01	00	03	30	17	42	01	12	04	09
23	01	00	03	30	17	42	02	12	04	09
24	01	00	03	30	17	42	03	12	04	09
25	01	00	03	30	17	42	04	12	04	09
26	01	00	04	37	50	18	05	30	19	52
27	01	00	04	37	50	18	06	30	19	52
28	01	00	04	37	50	18	07	30	19	52
29	01	00	04	37	50	18	08	30	19	52
30	01	00	04	37	50	18	09	30	19	52
31	etc. : unrecorded									

Figure XII-13 Program Memory Area (example 1)

Example of encoding of the PMA of CD-R disc number 201514, with 4 Audio Tacks in the Program Area.

* frame 1 to 10: the Disc Identification is noted.
  In this case, this Item has been recorded separately, so this Item is repeated 10 times (uneven number of Items, see chapter V.4.2).
* frame 11 to 30: the start and stop times of Track 1 to 4 are noted.

As there is no Skip information, all four Tracks will be played back completely.

Frame Number	CONTROL & ADR	TNO	POINT	MIN	SEC	FRM	ZERO	PMIN	PSEC	PFRM
1	02	00	00	20	15	14	00	00	00	00
..	..	..	..	..	..	..	..	..	..	..
10	02	00	00	20	15	14	09	00	00	00
11	01	00	01	05	45	67	00	00	02	01
12	01	00	01	05	45	67	01	00	02	01
13	01	00	01	05	45	67	02	00	02	01
14	01	00	01	05	45	67	03	00	02	01
15	01	00	01	05	45	67	04	00	02	01
16	01	00	02	12	01	09	05	05	45	67
17	01	00	02	12	01	09	06	05	45	67
18	01	00	02	12	01	09	07	05	45	67
19	01	00	02	12	01	09	08	05	45	67
20	01	00	02	12	01	09	09	05	45	67
21	01	00	03	30	17	42	00	12	04	09
22	01	00	03	30	17	42	01	12	04	09
23	01	00	03	30	17	42	02	12	04	09
24	01	00	03	30	17	42	03	12	04	09
25	01	00	03	30	17	42	04	12	04	09
26	01	00	04	37	50	18	05	30	19	52
27	01	00	04	37	50	18	06	30	19	52
28	01	00	04	37	50	18	07	30	19	52
29	01	00	04	37	50	18	08	30	19	52
30	01	00	04	37	50	18	09	30	19	52
31	03	00	01	02	03	04	00	00	00	00
32	03	00	01	02	03	04	01	00	00	00
33	03	00	01	02	03	04	02	00	00	00
34	03	00	01	02	03	04	03	00	00	00
35	03	00	01	02	03	04	04	00	00	00
36	05	00	01	05	45	67	05	05	42	67
37	05	00	01	05	45	67	06	05	42	67
38	05	00	01	05	45	67	07	05	42	67
39	05	00	01	05	45	67	08	05	42	67
40	05	00	01	05	45	67	09	05	42	67
41	01	00	05	42	16	32	00	37	50	18
42	01	00	05	42	16	32	01	37	50	18
43	01	00	05	42	16	32	02	37	50	18
44	01	00	05	42	16	32	03	37	50	18
45	01	00	05	42	16	32	04	37	50	18
46	04	00	01	03	04	00	05	00	00	00
47	04	00	01	03	04	00	06	00	00	00
48	04	00	01	03	04	00	07	00	00	00
49	04	00	01	03	04	00	08	00	00	00
50	04	00	01	03	04	00	09	00	00	00
51	etc. : unrecorded									

Figure XII-14 Program Memory Area (example 2)

Example of encoding of the PMA of CD-R disc number 201514, with 5 Audio Tracks in the Program Area.
* frame 1 to 30: see Figure XII-13
* frame 31 to 35: Tracks 2, 3 and 4 are noted to be skipped.
* frame 36 to 40: Time Interval number 1 is noted to be skipped.
* frame 41 to 45: start and stop time of Track 5 is noted.
* frame 46 to 50: tracks 3 and 4 are unskipped.

As a result, Track 1, 3, 4 and 5 will be played back. Track 2 and the last three seconds of Track 1 will be skipped.

Frame Number	CONTROL & ADR	TNO	POINT	MIN	SEC	FRM	ZERO	PMIN	PSEC	PFRM
n	01	00	A0		absolute time		00	01	00	00
n+1	01	00	A0		absolute time		00	01	00	00
n+2	01	00	A0		absolute time		00	01	00	00
n+3	05	00	B1	00	00	00	00	02	01	00
n+4	05	00	B1	00	00	00	00	02	01	00
n+5	05	00	B1	00	00	00	00	02	01	00
n+6	01	00	A1		absolute time		00	05	00	00
..	..	..	..	..	..	..	..	..	..	..
n+9	05	00	B2	02	00	00	00	00	00	00
..	..	..	..	..	..	..	..	..	..	..
n+12	01	00	A2		absolute time		00	42	16	32
..	..	..	..	..	..	..	..	..	..	..
n+15	05	00	01	05	45	67	00	05	42	67
..	..	..	..	..	..	..	..	..	..	..
n+18	01	00	01		absolute time		00	00	02	01
..	..	..	..	..	..	..	..	..	..	..
n+21	05	00	02	42	16	32	00	40	00	00
..	..	..	..	..	..	..	..	..	..	..
n+24	01	00	02		absolute time		00	05	45	67
..	..	..	..	..	..	..	..	..	..	..
n+27	05	00	B1	00	00	00	00	02	01	00
..	..	..	..	..	..	..	..	..	..	..
n+30	01	00	03		absolute time		00	12	04	09
..	..	..	..	..	..	..	..	..	..	..
n+33	05	00	B2	02	00	00	00	00	00	00
..	..	..	..	..	..	..	..	..	..	..
n+36	01	00	04		absolute time		00	30	19	52
..	..	..	..	..	..	..	..	..	..	..
n+39	05	00	01	05	45	67	00	05	42	67
..	..	..	..	..	..	..	..	..	..	..
n+42	01	00	05		absolute time		00	37	50	18
..	..	..	..	..	..	..	..	..	..	..
n+45	05	00	02	42	16	32	00	40	00	00
..	..	..	..	..	..	..	..	..	..	..
n+48	01	00	A0		absolute time		00	01	00	00
..	..	..	..	..	..	..	..	..	..	..
n+51	05	00	B1	00	00	00	00	02	01	00
..	..	..	..	..	..	..	..	..	..	..
n+54	01	00	A1		absolute time		00	05	00	00
..	..	..	..	..	..	..	..	..	..	..
n+57	etc.									

Figure XII-15 Table of Contents in the Lead-in Area of an Audio disc

Example of encoding of the TOC for a CD-R disc with an audio session containing 5 Tracks in the Program Area. Track 2 and two Time Intervals should be skipped at play back.

- frame n to n+44: one complete encoding of Mode-1 (ADR=1), alternated with Mode-5 encoding.
- frame n+3 to n+23: one complete encoding of Mode-5 (ADR=5), alternated with Mode-1 encoding.

Frame Number	CONTROL & ADR	TNO	POINT	MIN	SEC	FRM	ZERO	PMIN	PSEC	PFRM
n	01	00	A0	absolute time			00	01	00	00
n+1	01	00	A0	absolute time			00	01	00	00
n+2	01	00	A0	absolute time			00	01	00	00
n+3	05	00	B0	22	30	00	02	63	00	00
n+4	05	00	B0	22	30	00	02	63	00	00
n+5	05	00	B0	22	30	00	02	63	00	00
n+6	01	00	A1	absolute time			00	01	00	00
..	..	..	..	..	..	..	..	..	..	..
n+9	05	00	C0	80	80	50	00	97	35	00
..	..	..	..	..	..	..	..	..	..	..
n+12	01	00	A2	absolute time			00	20	00	00
..	..	..	..	..	..	..	..	..	..	..
n+15	05	00	B0	22	30	00	02	63	00	00
..	..	..	..	..	..	..	..	..	..	..
n+18	01	00	01	absolute time			00	00	02	00
..	..	..	..	..	..	..	..	..	..	..
n+21	05	00	C0	80	80	50	00	97	35	00
..	..	..	..	..	..	..	..	..	..	..
n+24	01	00	A0	absolute time			00	01	00	00
..	..	..	..	..	..	..	..	..	..	..
n+27	etc.									
..	..	..	..	..	..	..	..	..	..	..

Figure XII-16 Table of Contents in the first Lead-in Area of a Multisession Data disc

Example of encoding of the TOC for a CD-R disc with one finalized data session containing 1 Track in the first Program Area. The start time of the second Program Area is given in POINT=B0.

- frame n to n+20: one complete encoding of Mode-1 (ADR=1), alternated with Mode-5 encoding.
- frame n+3 to n+11: one complete encoding of Mode-5 (ADR=5), alternated with Mode-1 encoding.

	Byte	Contents	Byte	Contents	Byte	Contents	Byte	Contents
Track Descriptor Table	0	54						
	1	44						
	2	49						
	3	01						
	4	50						
	5	00						
	6	01						
	7	04						
Track Descriptor Units	8	04	24	01	40	02	56	03
	9	80	25	91	41	91	57	90
	10	FF	26	00	42	00	58	FF
	11	FF	27	00	43	00	59	FF
	12	FF	28	32	44	64	60	FF
	13	00	29	00	45	00	61	00
	14	00	30	00	46	00	62	00
	15	00	31	00	47	00	63	00
	16	00	32	00	48	00	64	00
	17	00	33	00	49	00	65	00
	18	00	34	00	50	00	66	00
	19	00	35	00	51	00	67	00
	20	00	36	00	52	00	68	00
	21	00	37	00	53	00	69	00
	22	00	38	00	54	00	70	00
	23	00	39	00	55	00	71	00
non-used bytes							72	00
							..	00
							..	00
							2047	00

Figure XII-17 The User Data Field in the Track Descriptor Block of Data Track 4 (Mode=1)

* Byte number 0 to 7 is the Track Descriptor Table of Track 4.
* Byte number 8 to 23 is the Track Descriptor Unit 1 (Track 4).
* Byte number 24 to 39 is the Track Descriptor Unit 2 (Track 1).
* Byte number 40 to 55 is the Track Descriptor Unit 3 (Track 2).
* Byte number 56 to 71 is the Track Descriptor Unit 4 (Track 3).
* The Pre Gap is 2 seconds (150 blocks) long.
* The Pre Gap also contains the Track Descriptors of track 1, 2 and 3.
* Track 4 is written Uninterrupted.
* Track 1 is Incremental written with a fixed Packet Size of 32 User Data Blocks. As an example, the track is 10 Packets long
* Track 2 is Incremental written with a fixed Packet Size of 64 User Data Blocks. As an example, the track is 20 Packets long
* Track 3 is Incremental written with a variable Packet Size. It is 640 blocks long (excluding the Pre Gap)

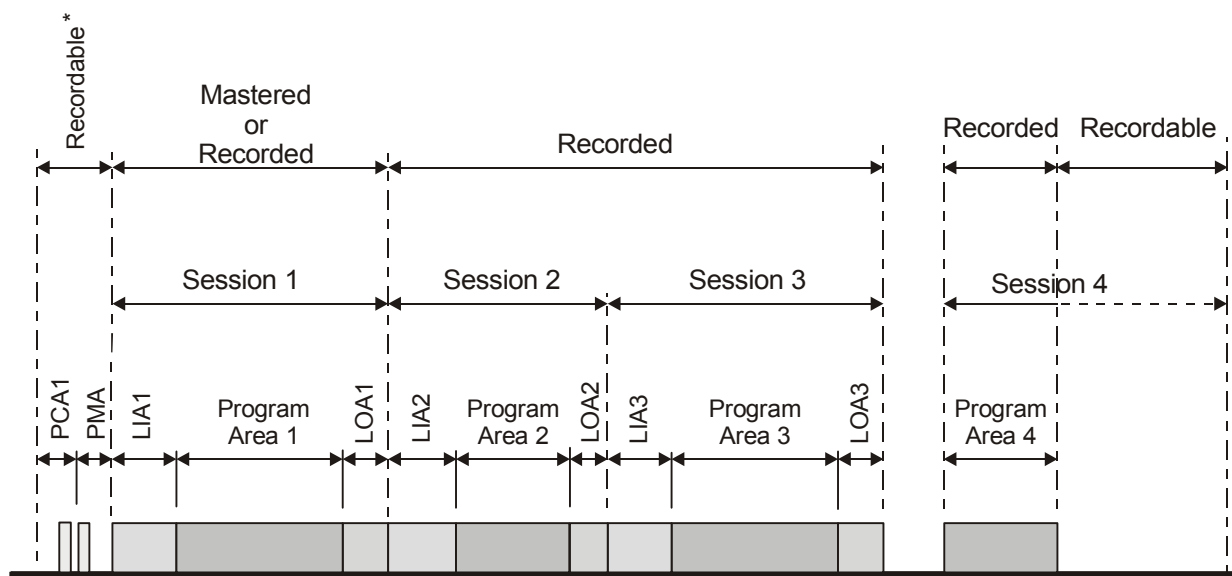



Figure XII-18 Example of the layout of a Multisession disc

Notes:

LIA = Lead-in Area

LOA = Lead-out Area

- Both the PMA and the PCA1 in this example are partially recorded and recordable. If Session 1 is Mastered, then the PMA is partially mastered, recorded and recordable.

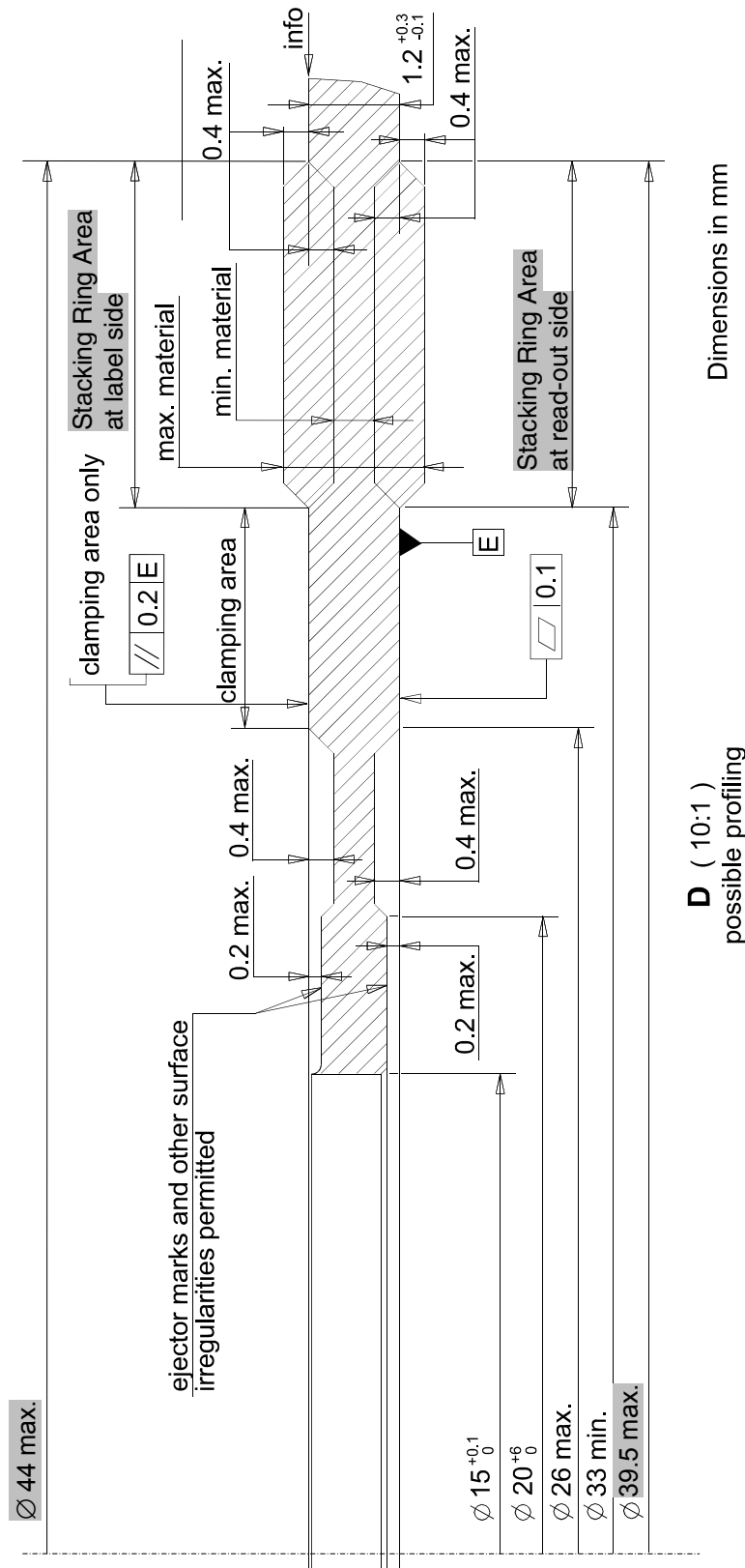



Figure XII-19 Details of the centre hole, clamping and stacking ring areas

Values and definitions in Figure XII-19 that are highlighted by grey background differ from the values of the latest version of the Red Book.

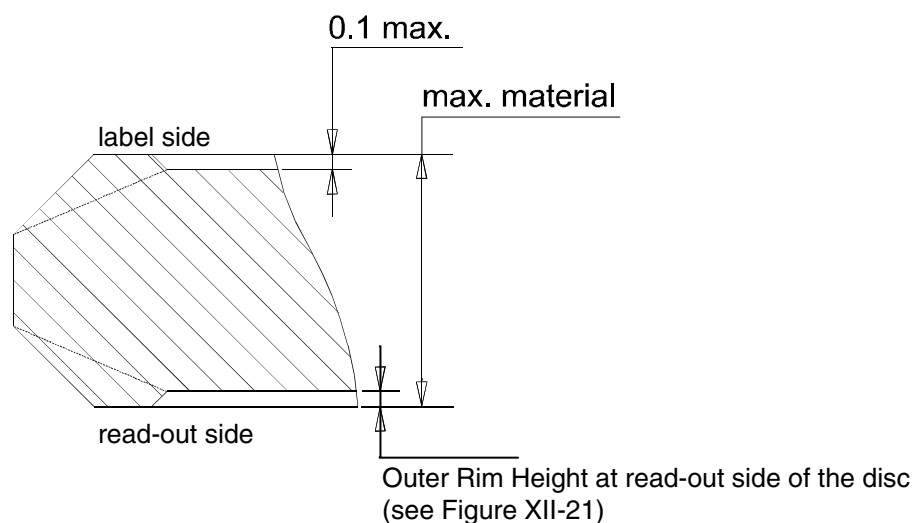



Figure XII-20 Outer Rim Height detail at outer diameter of the disc

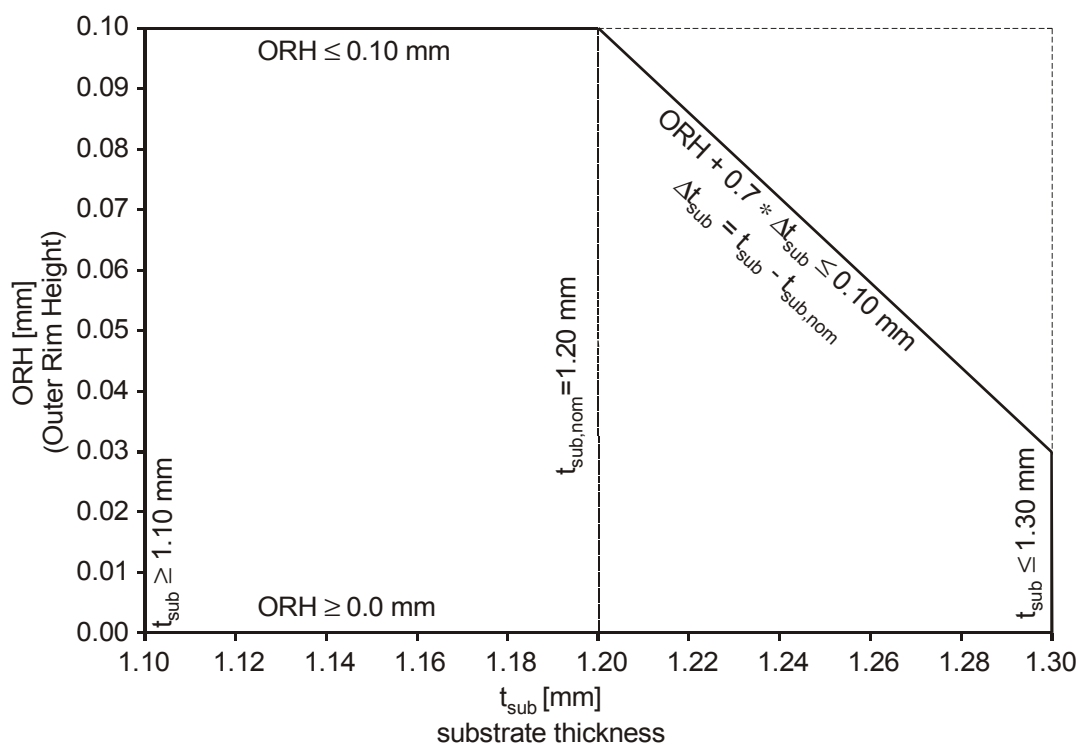



Figure XII-21 Allowed Outer Rim Height values in relation with the substrate thickness

At the outer diameter of the disc a rim is allowed, see Figure XII-20, both at the label side and the read-out side of the disc. The height of the outer rim at the label side of the disc is max. 0.1 mm (identical to the Red Book). The Outer Rim Height (ORH) at the read-out side of the disc is restricted as follows:

- ORH limit is 0.10 when $1.10 \leq t_{sub} \leq 1.20$ mm,
- ORH limit is $0.10 - 0.7 * \Delta t_{sub}$ when $1.20 \leq t_{sub} \leq 1.30$ mm,

as indicated in Figure XII-21, where t_{sub} is the substrate thickness of the disc at the data area and $\Delta t_{sub} = t_{sub} - t_{sub,nom}$.

XIII. Attachments

recommendations and clarifications

XIII.1 Principles of operation

Recorded information:
In the Information Area, the CD-R disc contains a spiral shaped groove in the sensitive layer. This groove is not a perfect spiral, but is wobbled in order to obtain motor control and timing information.
Recording takes place in the groove by locally heating up the sensitive layer with a laser spot. The laser output is modulated with the information to be recorded.
The parts of the disc that were heated up during recording show a reflection decrease after recording, and are called pits.
The encoded Audio or Data information is stored in the length of these pits and in the distance between them. These lengths and distances only take discrete values.

During playback of the disc, the scanning light spot is diffracted by the recorded pits in the sensitive layer. The optical power that is diffracted back into the objective lens, is modulated according to the encoded Audio or Data information. The modulated photo current is called the High Frequency (HF) signal.

The requirements for a recorded CD-R disc are nearly the same as the requirements for a conventional CD disc (see Red Book). Therefore the recorded CD-R disc can be played back on any conventional CD-player.

Tracking Information:
An off-track position of the scanning spot results in a diffraction pattern that is asymmetrical in the radial direction of the disc. Subtraction of the powers diffracted into the two halves of the aperture of the objective lens yields a servo signal for track following.

XIII.2 Measurement of the disc reflectivity

XIII.2.1 Specification

For a CD-R disc, the following requirements concerning reflection must be fulfilled:

- $R_0 > 0.65$ for blank and recorded discs
- $R_{TOP} > 0.60$ (chapter 0.8.4) for recorded discs, with $R_{TOP} = R_0 * I_{TOP}/I_0$ (see chapter I.4.4).
- $|\Delta R_{TOP}/\langle R_{TOP}\rangle| < 3\ \%$ (Red Book 8.5, f < 100 Hz) for recorded discs

R_0, the reflection and double pass substrate transmission measured on a mirror portion on the inside or outside of the disc, only depends on the layer reflection value and on substrate absorption.
Looking at the definition, it can be seen that R_{TOP} depends on R_0 and on the ratio I_{TOP}/I_0. This ratio may be significantly lower than 1 due to Radial Contrast on the blank disc and optical crosstalk of adjacent pits. The magnitude of these phenomena may depend on read-out polarization.
So, R_{TOP} is a more complicated parameter than R_0 but also more relevant because it is measured in the part of the CD which is played back.

XIII.2.2 Calibration & measurement procedure

The reflection of a CD-R disc is measured on a focused set-up as specified in chapter II: The Read Only Optical Pick Up (1 and 2), see Figure XIII-1. To minimize birefringence effects, a non-polarizing beam splitter should be used.
For regular calibration of the set-up, the R_{TOP} value provided with PHILIPS Test Sample 5B can be used as a reference value.
To obtain correct reflection values the following straightforward routine should be followed:

(i) measure calibrated reference disc (having reflectivity R_{REF}): V_{REF} (in arbitrary units)

(ii) measure disc to be measured: V_X (in same units)

(iii) calculate:

$$R_x = \frac{V_x}{V_{ref}} * R_{ref}$$

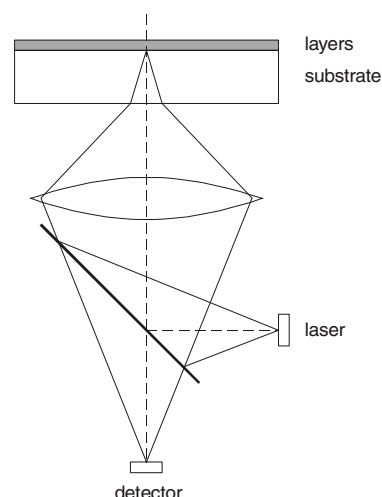



Figure XIII-1 Schematic set-up for reflectivity measurements

XIII.2.3 Notes

XIII.2.3.1 Parallel vs. focused

Measurement of the disc reflection is done routinely by comparing with a calibrated reference disc. According to the Red Book, this reference disc must be calibrated with a parallel beam. Comparison with the reference value however, is done on a normal CD player set-up (see Figure XIII-1), hence in a focused way. This is allowed provided that the substrates of the discs have equal index of refraction. In this way focused reflection measurements are 'upgraded' to parallel values.

XIII.2.3.2 Reference disc

For routine measurements, use of test sample 5B as a reference disc will provide sufficient accuracy. For exact calibration one needs a reference disc which has no birefringence and is independent of player parameters. Also, it should have a substrate having index of refraction equal to that of polycarbonate: $n \approx 1.57$.

A good, stable reference disc can be made according to the following specifications:

- glass substrate; n = 1.57; double pass absorption < 1%; d = 1.2 mm.
- Au reflecting layer; d > 100 nm; protective lacquer on top.

R_{REF} is measured with a substrate incident parallel beam at λ = 780 nm in such a way that front surface and internal reflection are included in the measurement (see Figure XIII-2).
When sputtering / evaporation conditions are optimized, $R_{REF} > 0.96$ should be reached. The R_{REF} value found can now be used as an absolute reference value.

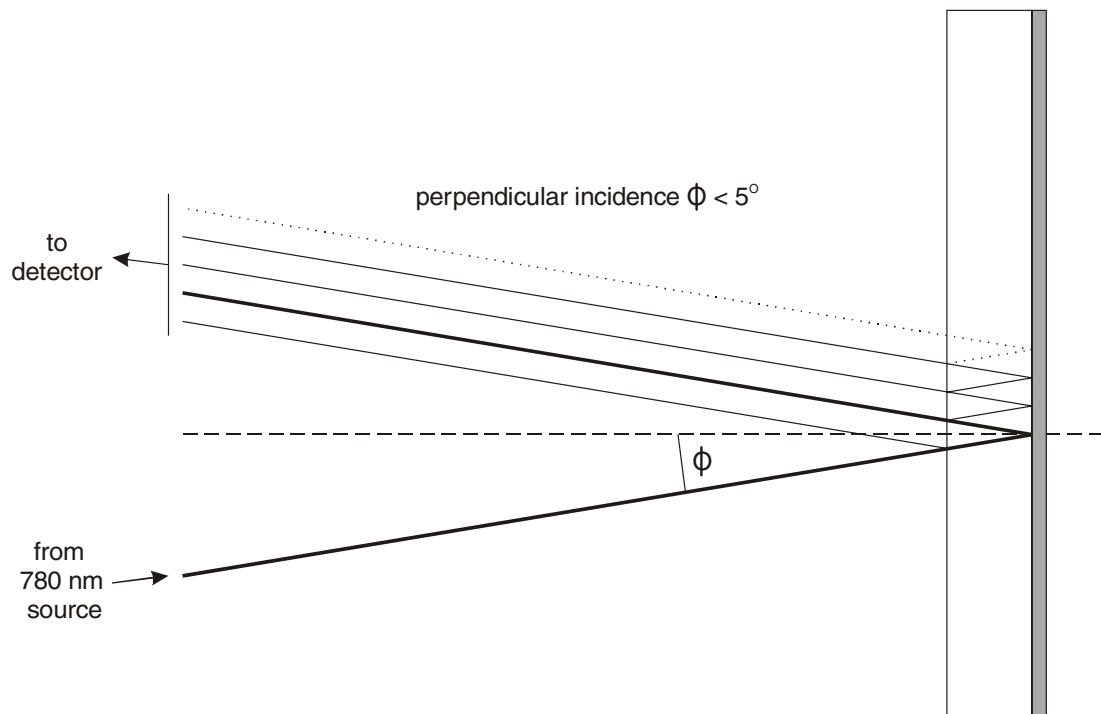



Figure XIII-2 Schematic set-up for calibration of reference disc

XIII.3 Optimum Power Control and Recording Conditions

XIII.3.1 Optimum writing power

The laser power and write strategy that should be used for recording a disc is dependent on the disc, the recorder and the recording speed.

For the disc there are four main parameters involved:

- The sensitivity of the recording layers to laser power at a given wavelength and disc temperature
- The change in sensitivity when the laser wavelength is changed.
- The change in sensitivity when the disc temperature is changed.
- The "pit-formation mechanism" in the recording layer, which is dependent on the applied layer technology.

For the recorder the three main parameters involved are:

- The dimensions and optical quality of the laser light spot at the recording layer.
- The applied write strategy.
- The actual wavelength of the laser when recording the disc (see attachment XIII.8).

This wavelength depends on e.g.:

- the type of laser
- the spread in wavelength for each individual laser of this type (and so for each individual recorder).
- the temperature of the laser.

As the optimum writing power P_{WO} depends on the disc, the recorder and the recording speed that are actually used, this power should be determined for each recorder/disc combination at the actual recording speed. Such a determination of the actual optimum writing power P_{WO} is called an **O**ptimum **P**ower **C**ontrol procedure (OPC procedure).

XIII.3.2 Asymmetry and optimum writing power

For different writing powers, the asymmetry of the recorded EFM data is different.
By test recording random EFM data with different writing powers, and measuring the resulting asymmetry in the HF signal, the optimum writing power for the specific combination of disc and recorder at a specific recording speed can be obtained.
Figure XIII-3 shows schematically the procedure with the OPC and write strategy. The main signals that are influenced by the applied write strategy and power level are the modulation, the asymmetry (β) and the jitter/effect-length. In practice the asymmetry appears to be a sensitive and easy to handle parameter for OPC.

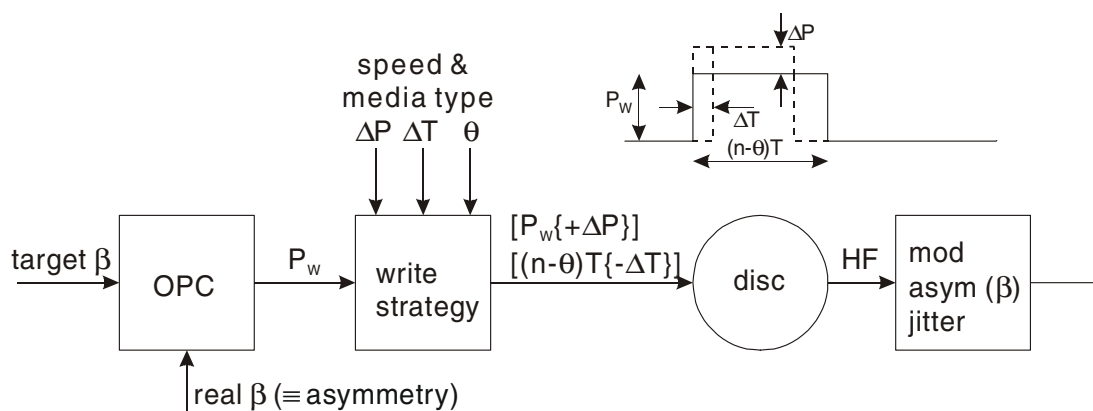



Figure XIII-3 Schematical diagram of OPC procedure

XIII.3.2.1 Measurement of asymmetry by means of β

Using the definition of asymmetry in the Red Book directly, may result in complicated recorder electronics. Therefore a different parameter is used as a representation of asymmetry. This parameter β is based on using the AC coupled HF signal before equalization.
We define: $\beta = (A_1 + A_2)/(A_1 - A_2)$ as the difference between the peak levels A_1 and A_2 (A_1+A_2), normalized to the peak-peak value (A_1-A_2) of the HF signal.
See Figure XIII-4.
β defined in this way, will be approximately equal to the asymmetry, see Figure XIII-5.
Zero asymmetry of the measured HF signal will, in general, correspond to $\beta \approx 0$.

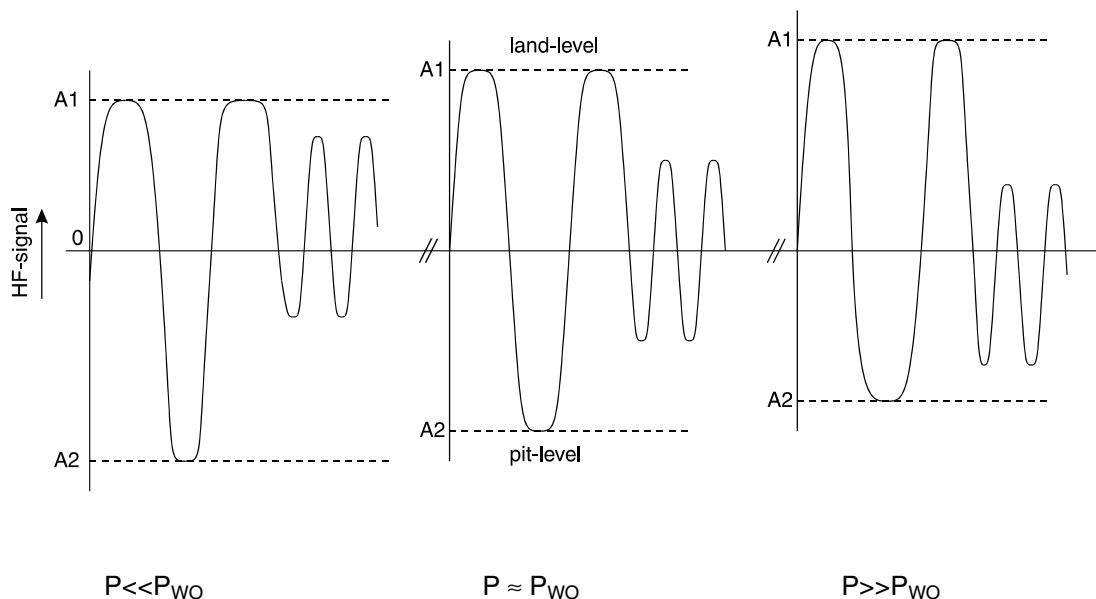



Figure XIII-4 AC-coupled HF signals recorded with different writing powers

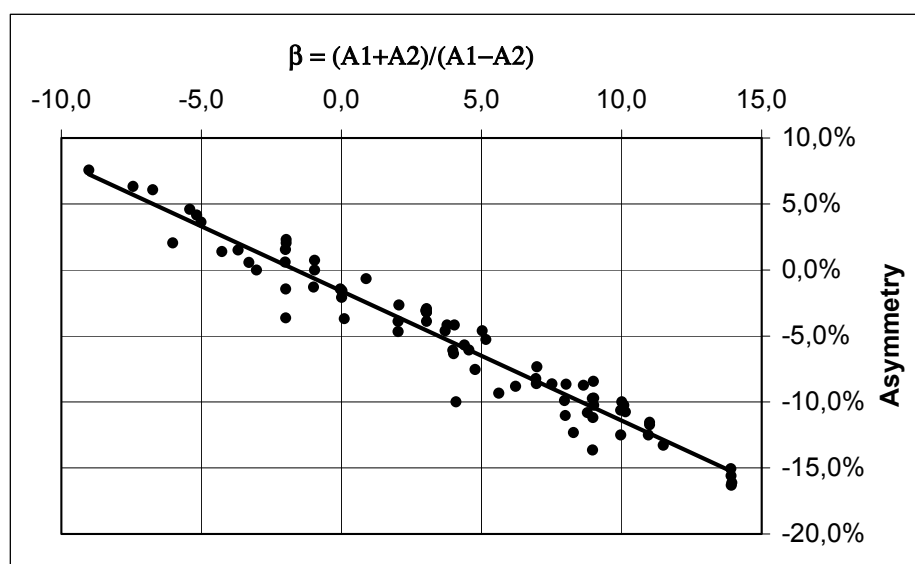



Figure XIII-5 Relation between β and asymmetry (experimentally determined)

XIII.3.3 The OPC procedure

To facilitate the OPC procedure, an indicative value (an estimation) for the writing power is given at several writing speeds. The Indicative Optimum Writing Power for 1x writing speed is encoded as special information in the ATIP during the Lead-in Area (see chapter IV.4.1).

Indicative Optimum Writing Powers are also given for the Lowest and Highest Test Speeds, as they are encoded in the ATIP during the eXtended Information Area and the Additional Capacity & Lead-out Area (see chapter IV.4.5).
These values can not be used as the exact optimum writing power for the actual disc/recorder/speed combination, but can be used as a starting value for an OPC procedure.
As the setpoint in the OPC procedure, for the Highest Test Speed the target β value indicated in ATIP is used (see chapter IV.4.4.4), while for the Lowest Test Speed β = 4% is used.

remark 1:
β is as measured with read-only pick-up (2), see chapter II. That means that, for each recorder design a translation has to be made from the recorder read-out conditions to the conditions of read-only pick-up (2).
remark 2:
As described in section II.4.18.4, the guaranteed width of the power window corresponds to a β range of 8%. In order to fulfill this specification on all discs, it is recommended to design the OPC procedure in such a way that reproducibility of the β value is better than ±4%.

The OPC procedure must be performed in areas on the CD-R disc that are specially reserved for this purpose: the **P**ower **C**alibration **A**reas (PCA1, PCA2, see chapter V.3).

XIII.3.4 Write strategy parameters at other speeds

It is recommended that CD-R recorders compliant with this volume 2 use the indicated test speeds as follows:
- The Highest Test Speed indicates the highest speed at which the disc has been verified,
- An estimate for the write parameters at any intermediate speed can be determined by linear interpolation between the parameters at 4x and the Highest Test Speed as indicated in ATIP.

Note: Disc Manufacturers should design media with a reasonable "linear" behavior of the write strategy parameters over the speed range indicated in ATIP.

This CD-R volume 2 document is prepared for future upgrades in recording speed. For this version, the highest speeds are 16x, 20x, 24, or 32x. It is expected that future versions will define write parameters at speeds above 32x. These test speed values have been defined already in chapter IV.4.4.2, but are still reserved and shall not be used for media according to this version of volume 2.

XIII.4 Environment: operating and storage conditions

Operating Conditions:
Rapid changes in temperature and humidity within these ranges may cause too large a deflection. Recovery times up to several hours have to be taken into account before reading from or recording in discs.
Recommendation: No condensation may occur on the disc.

Storage Conditions:
For storage and transport of discs before and after recording the following climatic tests are used to simulate typical conditions:

Dry Heat Test according to IEC 68-2-2 Ba

Temperature	:	55 ^{o}C
Relative Humidity	:	max. 50% at 35 ^{o}C
Storage Time	:	96 hrs.

Cyclic Damp Heat Test according to IEC 68-2-30 Db

Temperature	:	40 ^{o}C max.
Temperature	:	25 ^{o}C min.
Cycles	:	6
Relative Humidity	:	95%
Cycle Time	:	12 + 12 hrs.

After these tests one should allow for some recovery time before reading from or recording in tested discs.

XIII.5 Light fastness of the disc

Light fastness of the CD-R disc should be tested with an air cooled Xenon lamp and test apparatus complying with ISO-105-B02.

Test conditions:

- Black Panel Temperature : < 40 °C
- Relative humidity: : 70 - 80 %

Disc illumination:

- Through the substrate, normal incident.
- Disc not packed, out of cassette.

Requirement:
All disc specifications (chapter II) must be fulfilled, after illumination with a Xenon lamp corresponding with the European Wool Reference #5 (see ISO-105-B02).

Remark:
The change in color of the CD-R disc is irrelevant for this test.

XIII.6 Push Pull magnitude and the Normalized Push Pull Ratio

The definition of the Push Pull Amplitude in the Orange Book is basically the same as in the Red Book chapter 15. and 15.1.

- For the recorded part of the CD-R disc, the definition is the same as in the Red Book, and so the normalization is to I_{top}: $|I_1 - I_2| / I_{top}$ at 0.1 µm offset = 0.08 - 0.12.

- For the unrecorded part of the CD-R disc no I_{top} value is available. I_g is chosen for normalization, because this signal is available when tracking in the unrecorded groove: $|I_1 - I_2| / I_g$ at 0.1 µm offset = not specified.

There is no range specified for Push Pull amplitude before recording, because a more important value is the ratio of the Push Pull signals before and after recording. This is because the servo electronics have to deal with both recorded and unrecorded parts of a partially recorded disc, and so with two different Push Pull signals. As the dynamic range of the servo electronics is limited, the allowed ratio in Push Pull signals should be specified. Therefore the Normalized Push Pull Ratio (NPPR) is defined as:

$$\frac{|I_1 - I_2| / I_g}{(|I_1 - I_2|)_a / I_{ga}} = 0.5 - 1.3$$

where: I_g = groove level before recording.
I_{ga} = averaged groove level after recording: the averaged (τ=15 µs) HF signal before AC coupling.
This signal is chosen for normalization because it is actually used by the servo electronics for tracking in a recorded groove.

note: The specification for Push Pull magnitude after recording has been changed from 0.04-0.09 to 0.08-0.12 in order to facilitate design of pre-grooved CD-R media and to align CD-R with CD-RW.

XIII.7 Measurement of the groove wobble amplitude

The wobble amplitude in nm cannot easily be measured directly. However, it can be derived from the normalized wobble signal. The theoretical results for such a derivation are given below.

Relation between normalized wobble signal and wobble amplitude
According to specification point I.4.4, the wobble signal I_w can be seen as:

$$I_W = A * \sin \frac{2 * \pi * a}{p} \qquad (1)$$

where a = wobble amplitude in nm (typical 30nm)
p = track pitch of the radial error signal
A = the peak value of the radial error signal

In Figure XIII-6 and Figure XIII-7 the parameters a, p, A and I_w are shown. The averaged centre of the groove is taken as point 'o'. The groove has a peak displacement of 'a' (wobble amplitude) from the averaged centre of the groove to the actual centre of the groove. The normalized wobble signal can now be defined as:

$$\frac{I_{W\text{-rms}}}{(I_1 - I_2)_{pp}} = \frac{I_W}{2 * A * \sqrt{2}} = \frac{\sin(2 * \pi * a/p)}{2 * \sqrt{2}} \qquad (2)$$

where

$$I_{W-\text{rms}} = I_W / \sqrt{2}$$

$$(I_1 - I_2)_{pp} = 2 * A$$

The definition in (2) is consistent with specification point 16.2. in chapter II.4. The wobble signal (1) is not only dependent on the wobble amplitude 'a', but also the track pitch 'p'. Due to normalization, dependencies on groove geometry, spot shape and optical aberrations have been eliminated.

Tolerances of the normalized wobble signal
From the above formula for the normalized wobble signal, the tolerances as given in specification point 16.2 of chapter II.4 can be converted to nm for a given track pitch of 'p' = 1.6 microns.

Lower limit: 0.035 corresponds to 25 nm.
Upper limit: 0.060 corresponds to 43 nm.

Measurement suggestions
The wobble signal and the push-pull signal should be filtered before measurement. The wobble signal should be filtered through a 10 - 30 kHz bandpass filter, the push-pull signal through a 5 kHz lowpass filter. The push-pull signal should be averaged such that the influences of incidental defects in the disc are minimized.
The wobble signal should be measured at a location where the wobbled groove is in phase with the neighboring grooves. This corresponds to the positions with minimum wobble amplitude (this situation repeats with 1±0.4 Hz at N=1). In this case no enhancement of the wobble signal occurs, due to positive interference. It is possible that no true minimum is found due to low crosstalk levels between neighboring grooves. One must average the wobble signal such that the influences of incidental defects in the disc are eliminated.

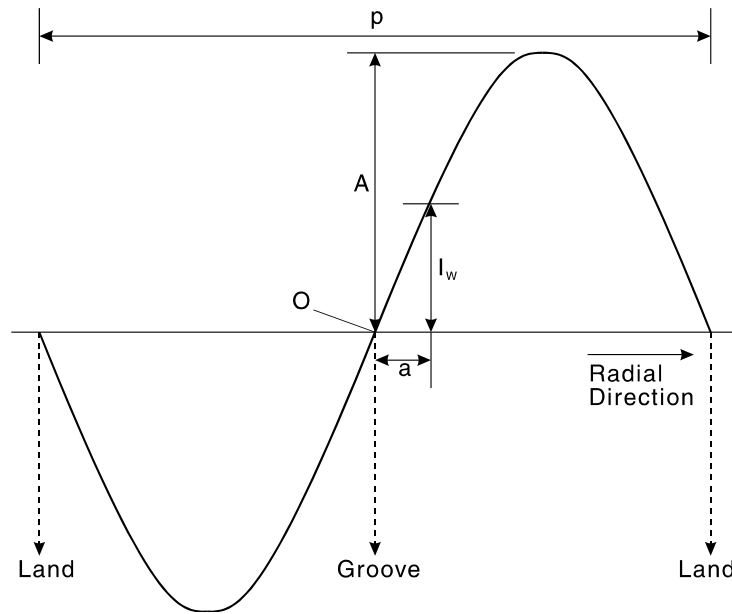



Figure XIII-6 The radial error signal

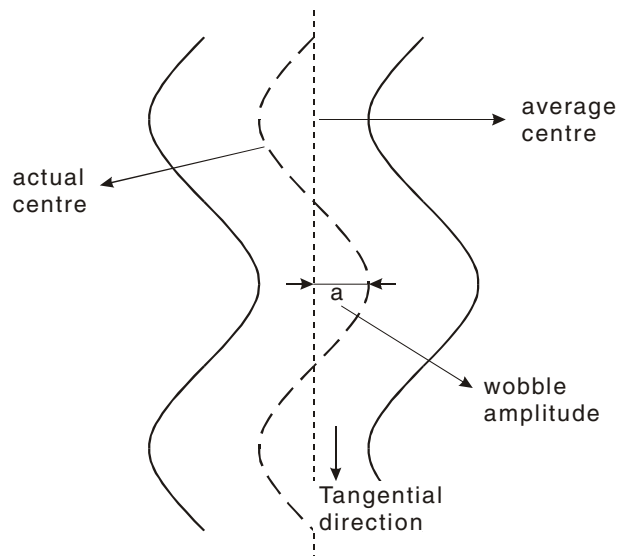



Figure XIII-7 The groove wobble

XIII.8 Wavelength dependency

When organic dyes are used as a recording layer, the CD-R disc characteristics are fundamentally wavelength dependent. On the other hand, the Laser Diode that generates the light used for recording and read-out of the CD-R disc has a wavelength with a certain tolerance. Moreover, the wavelength of the light emitted by the Laser Diode will depend on the temperature of the device.

This attachment intends to describe the tolerances in temperature and wavelength that are needed by the recorder. They can thus be considered as operating conditions for the disc. The disc shall comply with all specifications for the unrecorded and recorded disc within the operating conditions as defined by the shaded area in Figure XIII-8.

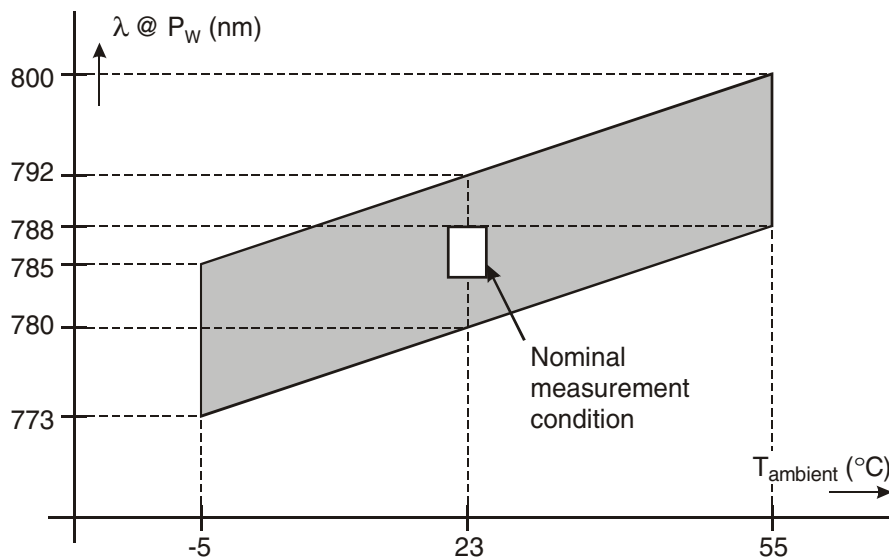



Figure XIII-8 Wavelength/Temperature diagram indicating the disc operating conditions

Note:
The temperature of the Laser Diode itself may be higher than the ambient temperature of the disc due to dissipation in the laser. In the graph of Figure XIII-8, a constant temperature difference is assumed between the disc and the laser.

XIII.9 Jitter, deviation and time errors

XIII.9.1 Jitter and deviation

See Red Book

XIII.9.2 Recorded time errors

Recorded (or mastered) time errors may be of single frequency type, e.g. caused by eccentricity. It is impossible to characterize all single frequency time errors which may occur on each recorded CD-R disc. Therefore, it is specified that the maximum value in µs of any single frequency time error must be below the value given in Figure XII-5 of this document (see also section 0.14.6).
In recorded CD-R discs however, recorded time errors are usually of a more complicated nature. When played back on a CD player with low Phase Lock Loop (PLL) bandwidth, C2 uncorrectable errors may be generated because of this. Therefore, it is specified that recorded time errors must be sufficiently low such that reliable play back without C2 uncorrectable errors is possible at a PLL bandwidth of 2.5 kHz (see also section 0.14.5).

XIII.10 The use of the Pre-Gap

In chapter V.6.5.1 is described how the Pre Gap must be used in the CD-R system. This attachment is a further clarification of that chapter.

In the Yellow Book the transitions of different kinds of Tracks are described.
For some transitions, a Pre Gap is prescribed:

- from an Audio Track to a Data Track Mode 1 or 2.
- from a Data Track Mode 1 to a Data Track Mode 2.
- from a Data Track Mode 2 to a Data Track Mode 1.

In chapter V.6.5.1 is described that in these cases, the Pre Gap must be according to these definitions in the Yellow Book or Green Book. An addition to this is, that the second part of the Pre Gap must include the Track Descriptor Block, instead of only zero data.

For some Track transitions, no Pre Gap is prescribed:

- from a Data Track Mode 1 to a Data Track Mode 1.
- from a Data Track Mode 2 to a Data Track Mode 2.

In chapter V.6.5.1 is described that in these cases, the Pre Gap must be 150 blocks long. It consist of block encoded data including the Track Descriptor Block.

Figure XIII-9 describes examples of the Track transitions. In this table, the contents of the subcode-Q channel TNO and INDEX are given for both the first and the second part of the Pre Gap (referred to as 1 and 2), as well as the Track Mode, Track Mode / Form, length of each part and the contents of the main channel data.

Some explanations to Figure XIII-9:

TDB	=	Track Descriptor Block
x	=	Track number of the "next" Track (in fact the Track number that is used in the data following the Pre Gap).
Length in blocks	=	The indicated length includes the Link-, Run-in and Run-out blocks that might be present in the Pre Gap (see also chapter V.6.5.1).
-	=	not applicable
Form	=	If Mode 2 is used according to the CD-ROM-XA specification, Form 1 or Form 2 must be used. If CD-ROM Mode 2 is used Form 1 or Form 2 is not applicable.

Track Transition	Subcode TNO		Subcode INDEX		Track Mode		Track Form		Length in Blocks		Main Channel Contents	
	1	2	1	2	1	2	1	2	1	2	1	2
Audio to Mode 1	x	x	0	0	-	1	-	-	≥75	≥150	Dig. silence	Block encoded, including TDB
Audio to Mode 2	x	x	0	0	-	2	-	1 or 2	≥75	≥150	Dig. silence	Block encoded, including TDB
Mode 1 to Mode 2	x	x	0	0	1	2	-	1 or 2	≥75	≥150	Block encoded, all zero data	Block encoded, including TDB
Mode 2 to Mode 1	x	x	0	0	2	1	1 or 2	-	≥75	≥150	Block encoded, all zero data	Block encoded, including TDB
Mode 1 to Mode 1	-	x	-	0	-	1	-	-	-	150		Block encoded, including TDB
Mode 2 to Mode 2	-	x	-	0	-	2	-	1 or 2	-	150		Block encoded, including TDB
Mode 1 or 2 to Audio	-	-	-	-	-	-	-	-	-	-	No Pre-gap, start Track with ≥ 2 seconds digital silence	
Lead-in to Mode 1	-	x	-	0	-	1	-	-	-	150		Block encoded, including TDB
Lead-in to Mode 2	-	x	-	0	-	2	-	1 or 2	-	150		Block encoded, including TDB, Subheaders 00

Figure XIII-9 Contents of the first and second part of the Pre Gap (1 and 2 in the table)

XIII.11 The use of addressing Method 1 and Method 2

The Addressing Method gives the relation between the Logical Block Number (LBN) and the Block Address in the Block Header. There are two methods:

Method 1:
LBN = (((MIN∗60)+SEC)∗75+FRAMES)-150

Method 2:
The LBN's upto and including the first User Data Block in a Track are calculated by:
LBN = (((MIN∗60)+SEC)∗75+FRAMES)-150
All the following LBN's are calculated by counting all User Data Blocks in the Track. This means that all Run-in blocks, Run-out blocks and Link blocks are excluded.

Basically, Method 1 is used on the entire disc. Only *within* an incrementally written Track with fixed Packets, Method 2 shall be used. For an incrementally written Track with variable length Packets, only addressing method 1 can be used.
For the entire disc, the first block of each Track has an address according to Method 1. This means that between the end of an incrementally written Track with fixed Packets and the next Track, there will be a discontinuity in the addressing of the Logical sectors. This is shown in Figure XIII-10: Example of addressing Method 1 and 2.

A further explanation of Figure XIII-10:
Track number 1 is written uninterrupted, and so addressing Method 1 is used. Track 2 is written incrementally with fixed Packet size, and so within the Track (after the first User Data Block) addressing Method 2 is used. As the Pre Gap of Track 2 is written separately, there is a link point at the end of this Pre Gap. The Link block and 4 Run-in blocks that precede the first blocks with user data, are included in the Pre Gap. The last LBN of Track 2 is (according to Method 2) 9383. The first LBN of Track 3 is (according to Method 1) 9550. So there is a discontinuity in the block numbering between Track 2 and 3.

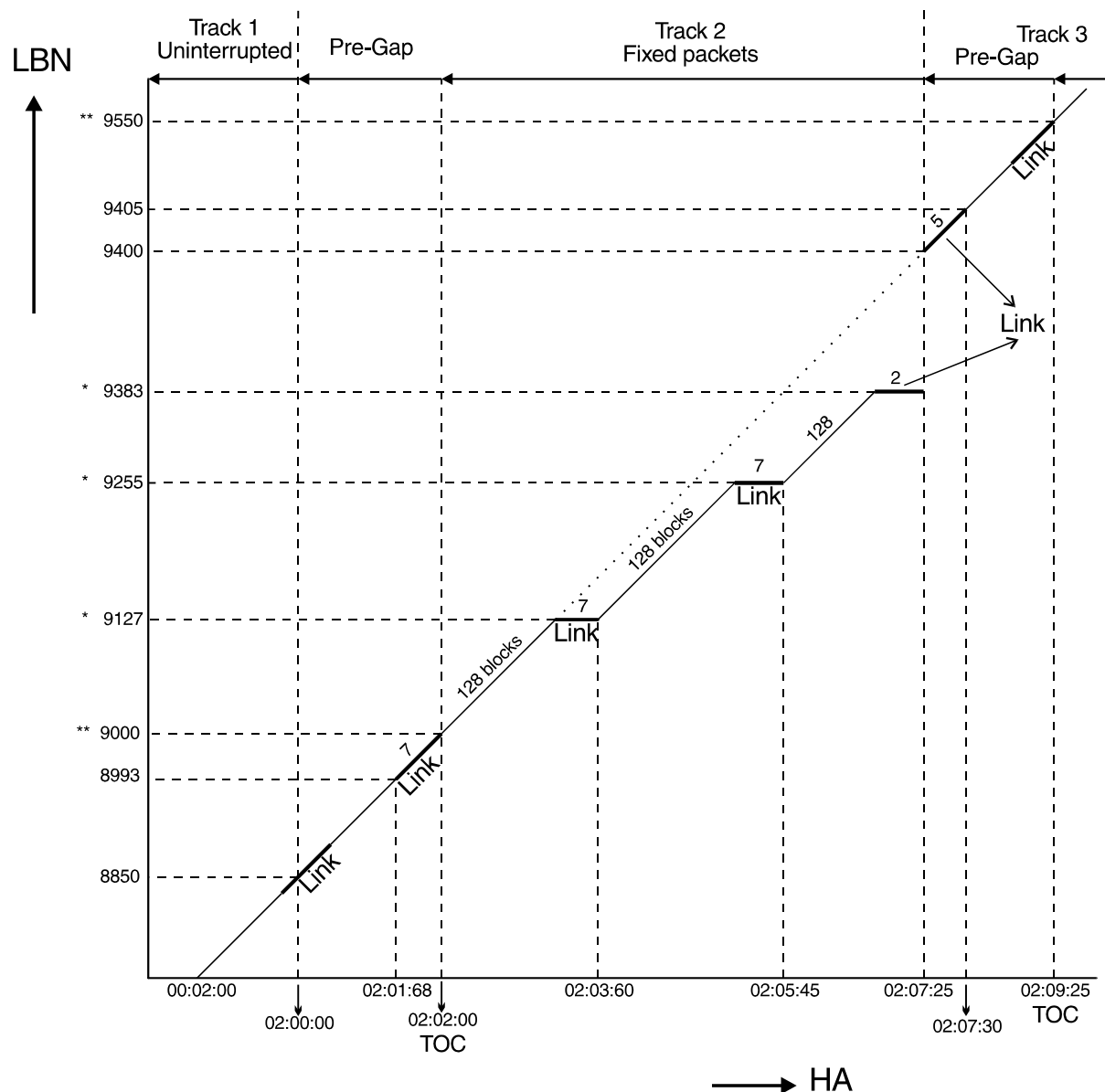



Figure XIII-10 Example of addressing Method 1 and 2

- Drawing not to scale
- * = Last user data block
- ** = First user data block
- HA = Header address
- LBN = Logical Block Number
- Link = 2∗RO + LB + 4∗RI
- RO = Run-out block
- LB = Link block
- RI = Run-in block
- TOC = Address in the TOC

XIII.12 Serial Copy Management System (SCMS)

XIII.12.1 Scope

XIII.12.1.1 General

The CD-R system adopts SCMS for consumer audio use.
The technical requirements, the recording rules and the playback rules which are required for the implementation of SCMS are given in the next chapters. All CD-R equipment for consumer audio use must fulfill these requirements and act properly according to these rules.

XIII.12.1.2 SCMS implementation

The implementation of SCMS in the CD-R system is based on:

1: Correct reading and interpretation of the recorder input signal, with regards to Copyright Status, Generation Status and Category Code.
2: Correct recording of the “Copy bit” in the CD-R disc, according to the Recording rules given in chapter XIII.12.5.
3: Correct reading of the “Copy bit” from the disc, and giving the correct output to the Digital Output Interface according to the Playback rules given in chapter XIII.12.4.

XIII.12.2 Normative references

IEC 60958: Digital Audio Interface, part 1 (General), part 3 (Consumer applications) and part 4 (Professional applications).

XIII.12.3 Technical requirements for CD-R equipment

All CD-R equipment for consumer audio use shall keep to the CD-R Playback Rules and CD-R Recording Rules as specified below. Category codes and copyright status bit included in the digital input signals shall not be deleted or modified and shall be monitored continuously and acted upon accordingly.

XIII.12.4 CD-R playback rules

The digital output shall be in accordance with IEC 60958.
An overview of the CD-R Playback Rules is given in Figure XIII-11.

Note: Alternative digital output may be used only in closed systems (e.g. double CD-R deck, CD/CD-R combinations or integrated stereo systems). The digital output of these systems shall provide for equivalent coding, specifically with respect to category code, copyright status and generation status, such that it is functionally compatible with SCMS.

XIII.12.4.1 Channel Status

XIII.12.4.1.1 Category code

CD-R equipment shall provide the category code 10000000 in the channel status bits of the digital output signal.

XIII.12.4.1.2 Copyright status bit

CD-R equipment shall provide the copyright status bit (bit 2 or "C-bit") in the channel status bits of the digital output signal. The copyright status shall be applied in the digital output signal as follows, in accordance with the status of the disc replayed. This copyright status on the disc is given by bit 1 of CONTROL in the subcode Q channel as described in chapter V.6.3 of this document (further on referred to as "Q-CONTROL bit 1").

- If "Q-CONTROL bit 1" is "0", the "C-bit" shall be set for "copyright protected: "C" is "0".
- If "Q-CONTROL bit 1" is "1", the "C-bit" shall be set for "not copyright protected: "C" is "1".
- If "Q-CONTROL bit 1" is alternating between "1" and "0" (referred to as "alt"), the "C-bit" shall be set for "home copy of copyright protected original": "C" = "alt".

XIII.12.4.1.3 Consumer/Audio bits

CD-R equipment for consumer audio use shall apply according to IEC 60958 the following in the channel status bits of the digital output :

- bit 0 is "0" (consumer use)
- bit 1 is "0" (audio)

Figure XIII-11 CD-R playback rules: Channel Status

Playback disc	Flags coming from disc:	Channel Status at digital output			maximum possible copies
	Q-CONTROL bit 1	"C-bit" = bit 2	Category code	L-bit = bit 15	
CD, CD-R or CD-RW	1	1	1000000	0	infinite
	0	0	1000000	0	1
	alt	alt	1000000	0	0

XIII.12.4.2 User data

Subcode Q-channel data from the disc shall be assigned to the User Data channel of the digital output according to IEC 60958.

XIII.12.5 CD-R recording rules

An overview of the Recording Rules are given in Figure XIII-12 "Recording rules" and Figure XIII-13 "SCMS logic diagram".
The next chapters XIII.12.5.1 to XIII.12.5.10 are additions to or clarifications of the Figure XIII-12 and Figure XIII-13.

XIII.12.5.1 The Serial Copy Management System (SCMS) applies to consumer audio CD-R equipment. Recording of digital non-consumer signals is inhibited. With channel status "bit 0" is "1" (professional source) recording is inhibited.

XIII.12.5.2 Recording of digital non-audio signals is inhibited. When channel status "bit 1" is "1", recording is inhibited.

XIII.12.5.3 In the case of a source which is without category information, e.g. without channel status bits or with an undefined category code, independent of the status of the copyright bit or the L-bit of the category code, the status "home copy of copyright protected original" shall be recorded on disc (Q-CONTROL bit 1= "alt").

XIII.12.5.4 Recording shall not be possible for digital input signals with a copyright status bit C-bit="alt" (alternating with a frequency from 4 to 10 Hz between "copyright protected" (C-bit="0") and "not copyright protected" (C-bit="1")) when the category code is from a compact disc digital audio signal (10000000).

XIII.12.5.5 For digital input signals originating from an analogue-digital converter, whether or not included as part of a CD-R equipment, with category code "01100XXL" or originating from other sources with category code "general", "00000000", the status "copyright protected" (Q-CONTROL bit 1 = "0" shall be recorded on disc, independent of the status of the copyright status bit or category code L bit of the input signal. This requirement shall not be applied to the analogue-digital converter of the type specified in chapter XIII.12.5.9.

NOTE: The digital input signal referred to in this chapter does not contain correct source information of the original signal before digitization. The analogue-digital converter is of the type which does not supply (correct) source information.

XIII.12.5.6 For digital input signals with a copyright status bit set for "not copyright protected" (C-bit="1"), the status "not copyright protected" shall be recorded on disc (Q-CONTROL bit 1= "1"), except for cases specified in chapters XIII.12.5.3 and XIII.12.5.5.

XIII.12.5.7 Recording shall be possible for digital input signals listed in Figure XIII-12 with a copyright status bit set for "copyright protected" (C-bit="0") and the L-bit set for “Pre-rec”. The status "home copy of copyright protected original" shall be recorded on disc (Q-CONTROL bit 1 ="alt").

XIII.12.5.8 Recording shall be inhibited for digital input signals with a copyright status bit set for "copyright protected" (C-bit="0"), except for the cases specified in chapters XIII.12.5.3, XIII.12.5.5 and XIII.12.5.7.

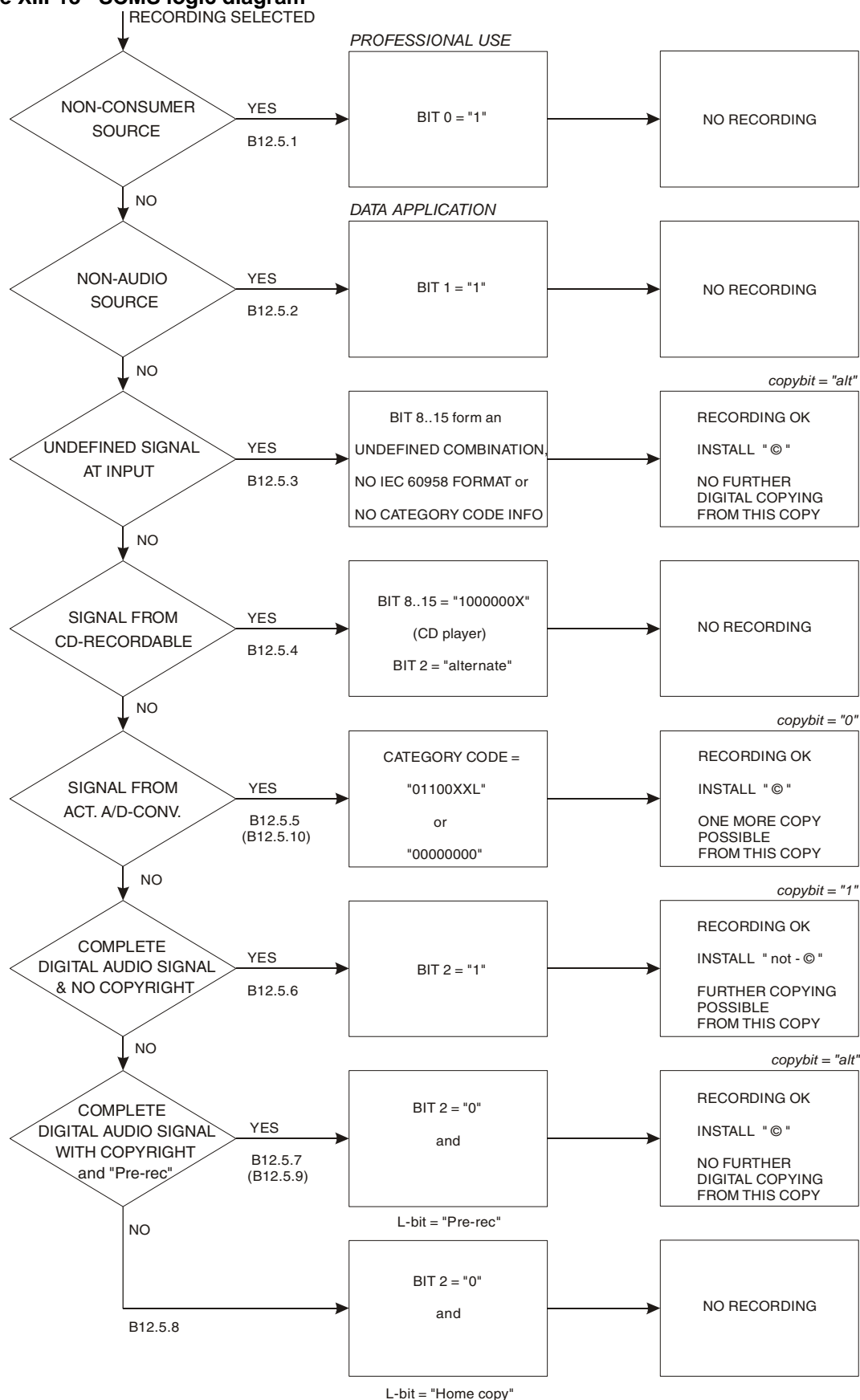
XIII.12.5.9 For digital input signals originating from an analogue-digital converter with category code "01101XXL", which can deliver original source information on copyright status from the analogue domain, the requirement stated in chapter XIII.12.5.5. shall not be applied.

XIII.12.5.10 For analog inputs, the status "copyright protected" shall be recorded on disc (Q-CONTROL bit 1 ="0").

Figure XIII-12 CD-R Recording Rules for all allowed input signals

Input source	Channel status of digital input signal C-channel acc.to IEC 60958			Recorded on CD-R disc	Maximum remaining serial copies
	Copy bit "C-bit"=bit 2	Cat.code bit 8..14	L bit bit 15	Q-CONTROL bit 1	
	Not copyright protected				
D/D converter	1	010xxxx	x	1	infinite
Magnetic prod.	1	110xxxx	x	1	
Music.instr.	1	101xxxx	x	1	
Fut.A/D conv	1	01101xx	x	1	
Sol.state rec.	1	0001xxx	x	1	
Experimental	1	0000001	x	1	
Laser-opt.prod.	1	100xxxx	x	1	
Broadcast recept.	1	001xxxx	x	1	
Broadcast recept.	1	0111xxx	x	1	
	Copyright protected		Home copy		
D/D converter	0	010xxxx	0	not recordable	0
Magnetic prod.	0	110xxxx	0		
Music.instr.	0	101xxxx	0		
Fut.A/D conv	0	01101xx	0		
Sol.state rec.	0	0001xxx	0		
Experimental	0	0000001	0		
Laser opt.prod.	alt	100xxxx	x		
Laser opt.prod.	0	100xxxx	1		
Broadcast recept.	0	001xxxx	1		
Broadcast recept	0	0111xxx	1		
	Copyright protected		Pre-rec		
D/D converter	0	010xxxx	1	alt	0
Magnetic prod.	0	110xxxx	1	alt	
Music.instr.	0	101xxxx	1	alt	
Fut.A/D conv	0	01101xx	1	alt	
Sol.state rec.	0	0001xxx	1	alt	
Experimental	0	0000001	1	alt	
Laser opt.prod.	0	100xxxx	0	alt	
Broadcast recept.	0	001xxxx	0	alt	
Broadcast recept.	0	0111xxx	0	alt	
General	x	0000000	x	0	1
Actual A/D	x	01100xx	x	0	1
no category code	x	-	x	alt	0
Analog signal	-	-	-	0	1

x = either "0" or "1"
alt = alternating between "1" and "0"
- = not applicable

Figure XIII-13 SCMS logic diagram

XIII.13 Running OPC

XIII.13.1 Introduction

The correct writing power for the CD-R disc is to be determined by means of an Optimum Power Calibration procedure as described in attachment XIII.3 of this document. However, after this calibration, the optimum power may change because of:

- power sensitivity fluctuation over the disc (although limited to $0.05 * P_{WO}$, see section II.4.18.5)
- wavelength shift of the laser diode due to change in operating temperature
- change of spot aberrations due to change in disc skew, substrate thickness, defocus, etc.
- changed conditions of disc and/or optics, when OPC was carried out a long time before actual recording (Disc Identification option, see section V.4.3).

The purpose of the Running OPC is to continuously adjust the writing power to the optimum power that is required. In this attachment the principle and possible implementation of Running OPC are explained.

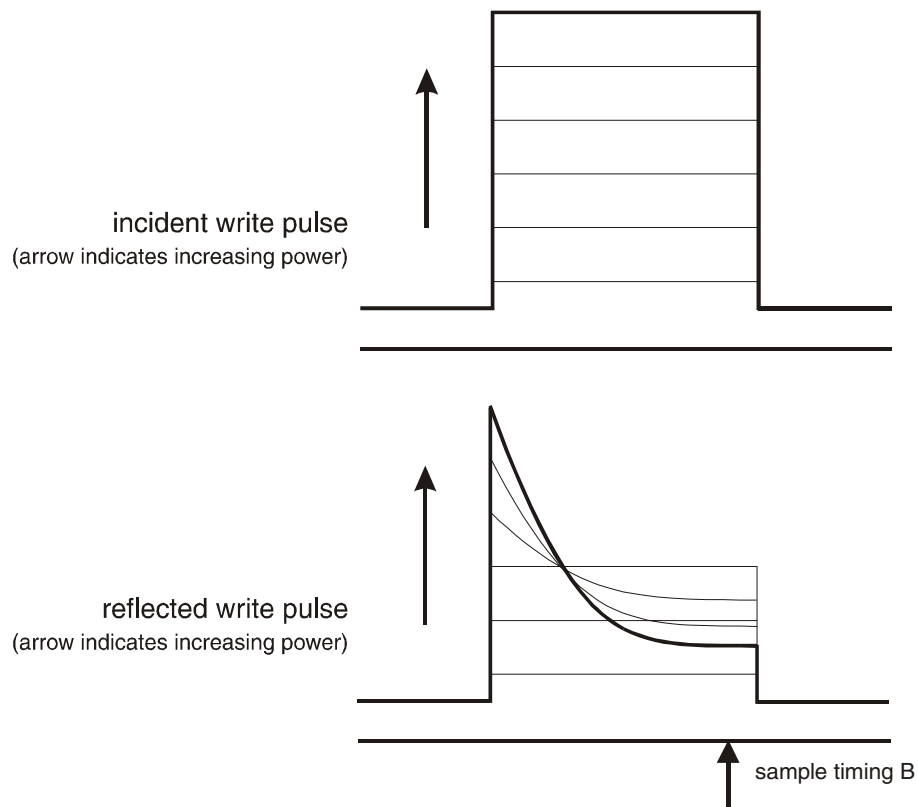



Figure XIII-14 Incident and reflected write pulses

XIII.13.2 Principle of Running OPC

By using Running OPC, the recording process is monitored continuously. In Figure XIII-14, the incident write pulse to the recording layer is shown and how it is reflected by that layer. As the peak power of the incident pulse is increased, the reflected pulse at sample timing B goes up in proportion to the incident pulse until the point where the physical change on the disc begins. At that point, the reflected level at sample timing B (B-level) decreases rapidly due to the pit formation. The reflected B-level as a function of incident writing power is shown for a typical CD-R disc and for 11T pulses in Figure XIII-15.

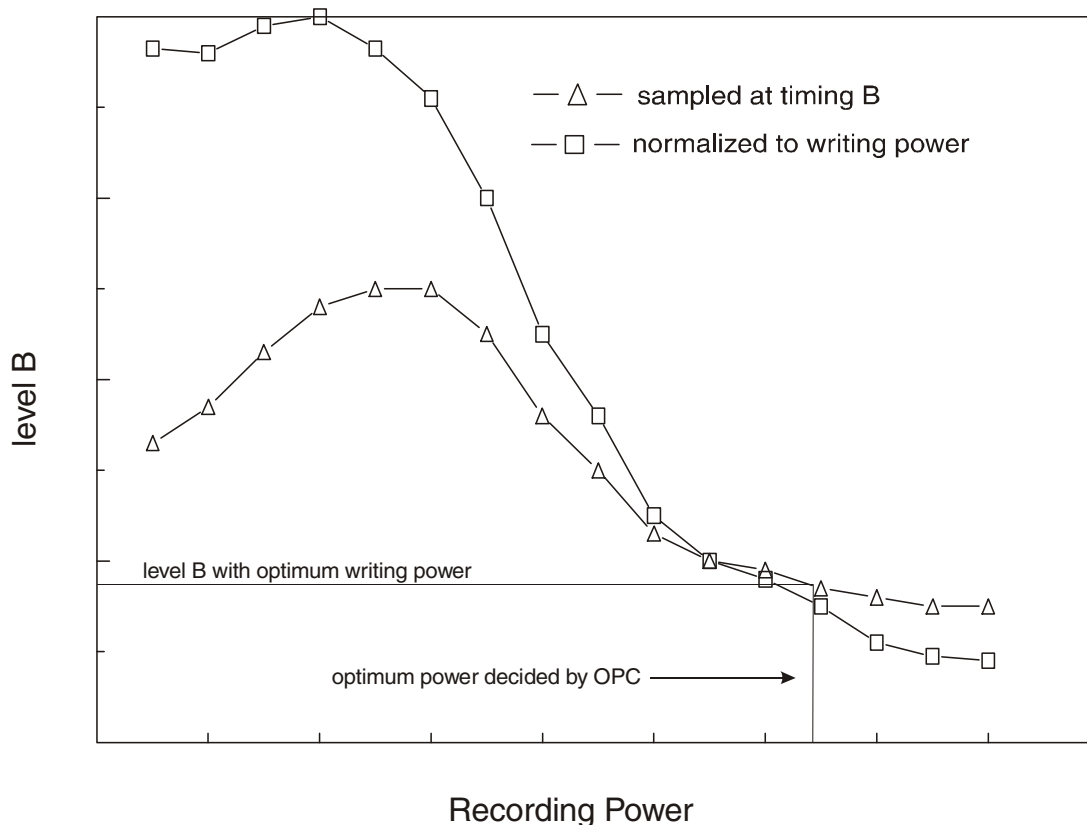



Figure XIII-15 Example of reflected B-level as a function of writing power (11T pulses)

Also shown in Figure XIII-15 is the B-level, when normalized to the writing power value. In that case, the B-level first remains constant, then drops steeply due to the recording process.

When the optimum writing power changes due to the reasons indicated in the previous section, the curves in Figure XIII-15 fluctuate in horizontal direction, hence, the B-level fluctuates. Also, β (or asymmetry) of the recorded signal changes. So, β (measured after recording) is a function of the B-level (measured during recording). The principle of the Running OPC is to keep the B-level constant by continuously adjusting the writing power. As a result, β of the recorded disc will be constant.

The procedure for the Running OPC is as follows:

- During the regular OPC procedure, the correct value for the reflected B-level is determined and kept in memory as a reference value.
- During recording, the actual reflected B-level is controlled in a control loop in which the actual value is kept as close as possible to the reference value.

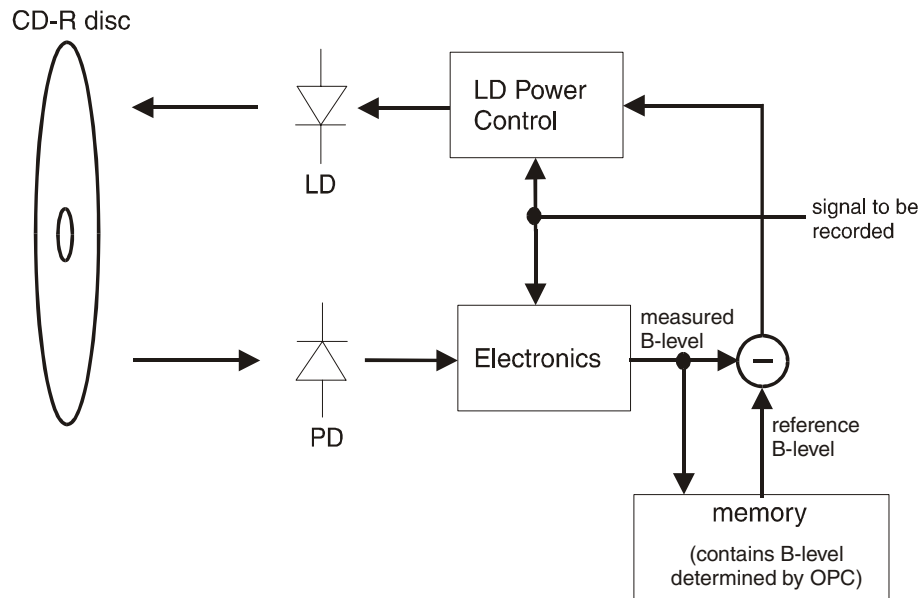



Figure XIII-16 Possible implementation of Running OPC

XIII.13.3 Possible implementation of Running OPC

A block diagram of a possible implementation is shown in Figure XIII-16. In the 'Electronics' block, the normalized B-level is determined from selected write pulses (e.g. 11T pulses). In order to cancel out the effect of reflectivity fluctuations, it is recommended to additionally normalize the reflected B-level by the disc reflectivity itself. The disc reflectivity can be monitored by applying a read power level (< 0.7 mW) between the write pulses and sampling the reflected signal between the pulses.

Recommendation:
Running OPC is recommended for use in all CD-R recorders.

XIII.14 Subpartitioning the partitions in the PCA Test Areas

XIII.14.1 Introduction

The normal use of the PCA1 and PCA2 (Power Calibration Areas, see chapter V.3) allows a maximum of 100 OPC (Optimum Power Control) procedures to be executed, where each procedure uses a full partition of 15 ATIP frames of the Test Area. 100 OPC actions might be insufficient, especially in the case of packet writing on one disc with different CD-R recorders.
To increase the maximum number of OPC possibilities on a disc, each partition of the Test Area is optionally divided into subpartitions. If subpartitioning is used, the requirements in XIII.14.2 to XIII.14.4 shall be applied.

XIII.14.2 Principle of subpartitioning

The specification of a partition is given in chapter V.3.1.
Each subpartition shall consist of an integer number of ATIP frames. The minimum length of a subpartition is 1 ATIP frame and the maximum length is 15 ATIP frames. Subpartitions within one partition can have different lengths. Subpartitions are allowed to span the borders of a partition. It is recommended not to leave gaps between subpartitions.
The Link Position for both the begin and the end of a subpartition has to be 0 ± 2 EFM frames after the end of the ATIP-sync.
Subpartitions are used from outside disc towards inside disc (as with partitions, see chapter V.3.1). Subpartitions shall be used in sequential order.

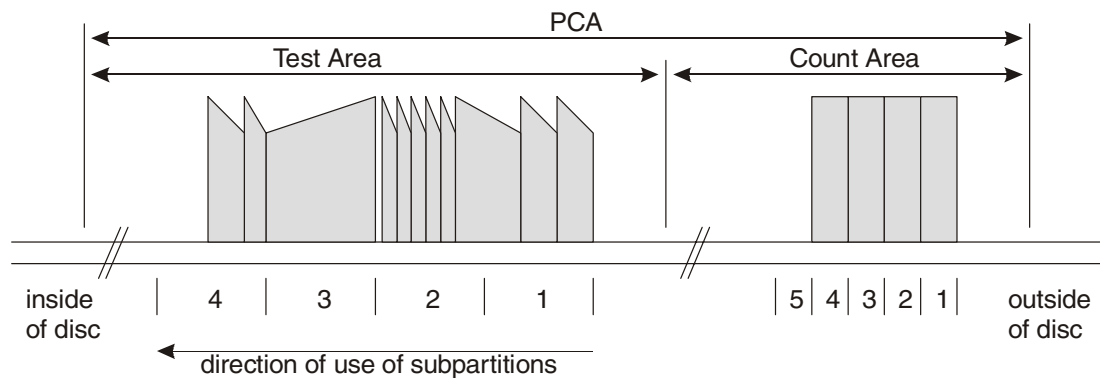
XIII.14.3 Use of the Count Areas

If a partition or a part of a partition in one of the Test Areas is used, then the corresponding Count Area shall be recorded with an EFM signal according to chapter V.3.2. Also when a subpartition crosses the border between 2 partitions, the Count Area corresponding to the last partition shall be recorded.

XIII.14.4 Power steps

To determine the optimum writing power for the disc, recordings with different writing power are made within a (sub)partition. These recordings are made in the normal recording direction, i.e. from inside disc towards outside disc.
At the beginning of an OPC procedure, the Count Area indicates the last used partition. When subpartitioning has been used, the start of the last subpartition inside the indicated partition has to be located by the recorder with a search procedure.
In order to guarantee a good detection of the transition between the unused part of the Test Area and the last recorded subpartition, the modulation at the start of the last recorded subpartition should be > 60%.
Some examples of how this could be achieved:
- the test recording starts with the highest power.
- the test recording starts with the lowest power. After completing the OPC procedure the subpartition is (partly) overwritten with a power level resulting in sufficient modulation.
- the test recording starts with the lowest power. After completing the OPC procedure an additional subpartition of 1 ATIP frame is written with a power level resulting in sufficient modulation.

Example of PCA with subpartitions:

- *partition 1:*
  used with 2 subpartitions of 5 ATIP frames each and the start of a subpartition of 9 ATIP frames (spanning the border between partition 1 and partition 2)
- *partition 2:*
  used with the continuation of a subpartition of 9 ATIP frames and 5 subpartitions of 2 ATIP frames each (leaving a gap)
- *partition 3:*
  used as a normal full partition (with increasing power steps)
- *partition 4:*
  in use (recorded with 2 partitions: 1 of 3 ATIP frames and 1 of 5 ATIP frames)

XIII.15 CDs21 Solutions Disc Identification Method

For “Disc Identification Method Specification” according to CDs21 Solutions see:
http://www.cds21solutions.org (for members only) or
http://www.licensing.philips.com/

XIV. List of changes

Differences between Orange Book, part II: CD-R, volume 2: Multi-speed, version 1.2, April 2002 and Orange Book, part II: CD-R, volume 2: Multi-speed, version 1.3, August 2006

Main Technical changes:
- Relaxation of the max. variation of asymmetry
- Reduction of the stacking ring area at read-out side of the disc
- Mechanical amendments to the rim height at outer diameter read-out side of the disc

V 1.3 Page:	Volume 2, version 1.3	Volume 2, version 1.2	remarks
-	Philips Intellectual Property & Standards Business Support Building WAH-2 P.O. Box 220 5600 AE Eindhoven The Netherlands Fax: +31 - 40 - 27 32113 Internet: http://www.licensing.philips.com/ E-mail: info.licensing@philips.com	Royal Philips Electronics System Standards & Licensing Licensing Support Building SFF-8 P.O. Box 80002 5600 JB Eindhoven The Netherlands Fax.: +31 - 40 - 27 32113 Internet: http://www.licensing.philips.com	Update
I-1	---	The existing system description for 1x, 2x and 4x speed "Recordable Compact Disc Systems, part II: CD-R, version 3.1" will be renamed to: "Recordable Compact Disc Systems, part II: CD-R, volume 1: 1x/2x/4x, version 3.1".	Deleted
I-6	Stacking ring area: The ring area between the clamping and the information area. In this area diverse shapes with protrusions and recesses are allowed, both on the read-out and label side. It is called the stacking ring area as this area is most used for creating a stacking ring at the read-out side of the disc. See Figure XII-19	---	Definition added
II-4	2.6 Outer diameter of stacking ring area, at read-out side	---	Added
II-6	Recommended max. variation of asymmetry	Max. variation of asymmetry	Relaxation
II-6	---	14.10 Phase Difference Voltage	Deleted

V 1.3 Page:	Volume 2, version 1.3	Volume 2, version 1.2	remarks
XII-1	Figure 19: Details of the centre hole, clamping and stacking ring areas Figure 20: Outer Rim Height detail at outer diameter of the disc Figure 21: Allowed Outer Rim Height values in relation with the substrate thickness	---	Added
XII-17	Figure XII-19 Details of the centre hole, clamping and stacking ring area	---	Figure added
XII-17	Values and definitions in Figure XII-19 that are highlighted by grey background have been aligned with the values of the latest version of the Red Book.	---	Added
XII-18	Figure XII-20 Outer Rim Height detail at outer diameter of the disc	---	Added
XII-18	Figure XII-21 Allowed Outer Rim Height values in relation with the substrate thickness	---	Added
XIII-1	---	Attachment 13: Phase Difference Voltage	Deleted
XIII-1	Attachment 15: CDs21 Solutions Disc Identification Method	Attachment 16: OSJ Disc Identification	Update
---	---	XIII-13 Phase Difference Voltage	Deleted
XIII-20	---	To be published in 1998; at present see: IEC 100C/193/CDV (part 1) IEC 100C/194/CDV (part 3) IEC 100C/195/CDV (part 4)	Footnote deleted. These items have been published.